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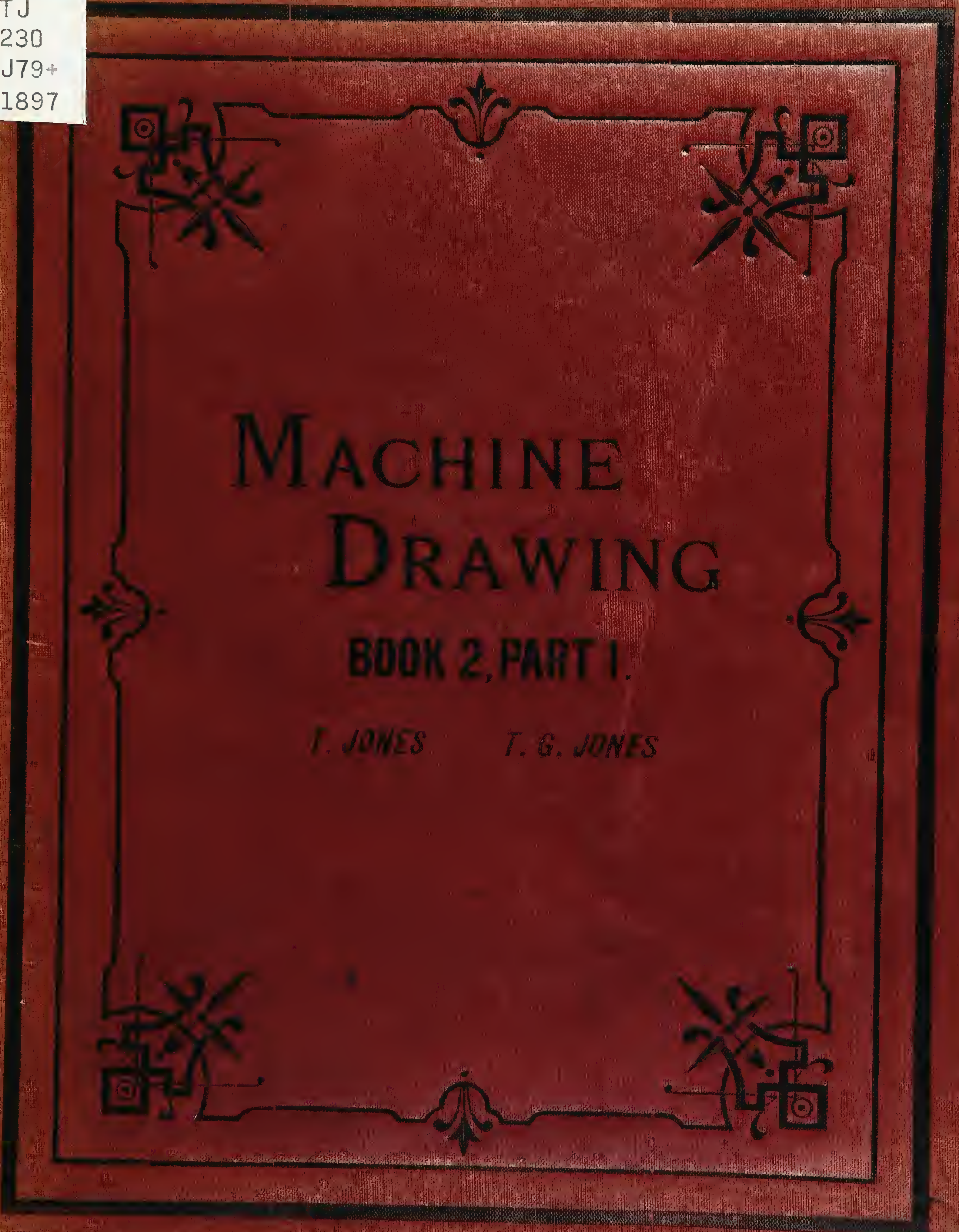

MACHINE DRAWING

BOOK 2, PART I.

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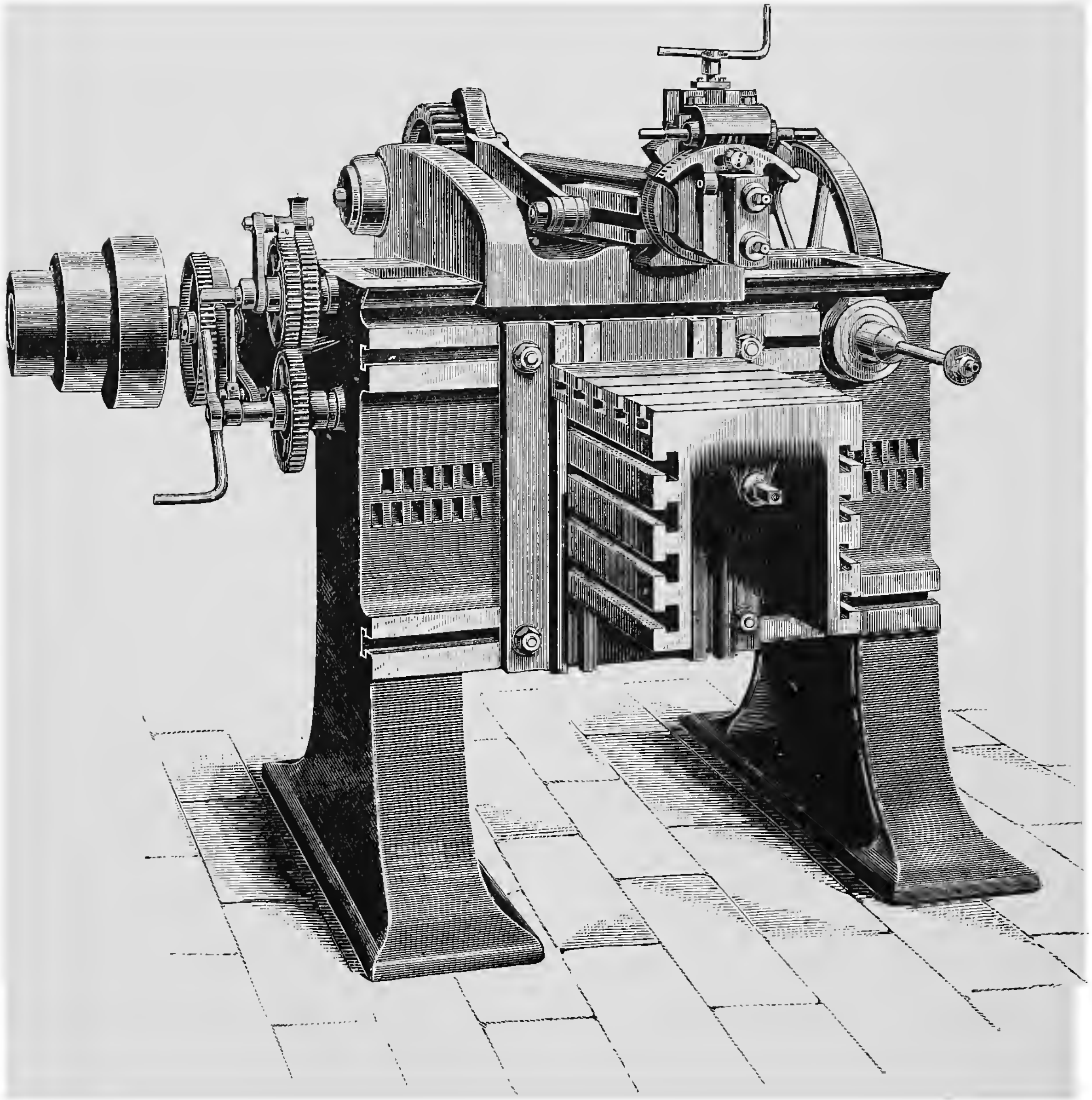

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Plate 12. Complete Drawing of Slotting Machine. COLOURED.
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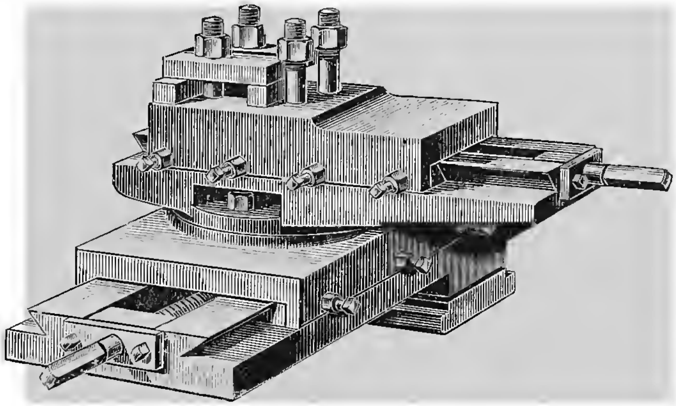

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PREFACE.

THE drawings of machine tools given in the following pages are all taken from actual machines constructed at the present time by expert engineers and tool makers.

The objection which is often made by our leading engineers and engineering journals that the drawing exercises, given to students in Technical Schools and Colleges, are of old fashioned and out of date machine details cannot therefore be urged in the case of the present volume.

The various elevations are projected one from the other, as explained in Book I. The object is supposed to stand in *front* of the vertical plane upon which it is projected, and not *behind* it.

All the drawings are fully dimensioned, and each detail whilst furnishing a drawing exercise for the student, is an example of the best device known for accomplishing the particular purpose for which it is used. The student is enabled to make a picture of a really existent machine detail, and also to learn the actual position and use of the detail in the machine. If of an inventive turn of mind he may be able to suggest some better device for effecting the same purpose.

The authors feel sure that the stimulation of the inventive faculty of the young engineer in the school, as well as in the workshop, is most desirable; his education will be sounder and more thorough. The knowledge of the exact use of a machine part is the best foundation upon which to build an improvement of it.

Calculations of the speeds of the driving and feed gears of the various machines are given, and in the Slotting and Shaping machines the varying velocities of the tool in the cutting and return strokes are shown graphically.

The student is also encouraged to make finished coloured drawings. Although this work may not be so important as the knowledge of correct construction, and the ability to make a good and accurate drawing, still it will in many cases be an incentive to the student to work out and finish in ink the various details. To copy Plates I. and XII. until neat and accurate drawings of the various details of the machines have been made, inked in and coloured, would be wasting time.

On behalf of engineering students generally, as well as on their own behalf, the authors hereby tender their warmest thanks to the undermentioned Manchester engineering firms, who have kindly furnished particulars from which the Plates have been prepared :—Messrs. Smith and Coventry Limited; Messrs. Hulse and Co. Limited; Messrs. Jno. Hetherington and Sons Limited; Messrs. P. R. Jackson and Co. Limited.

THOMAS JONES.
T. GILBERT JONES.

Manchester,
September, 1898.

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PLANING MACHINE, 2ft. × 2ft. × 4ft. STROKE.

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Plate I.—36″ DRILLING MACHINE.

GENERAL DESCRIPTION.

THE drilling machine, of which drawings are given on Plates I. to V. inclusive, is made by Messrs. Smith and Coventry Ltd., Manchester, and is capable of drilling holes from $\frac{3}{16}$″ to 4″ diameter in a piece whose height does not exceed 36″.

The counter-shaft for the machine is fitted with two fast and two loose pulleys, which are connected with the main driving shaft by open and crossed belts. This arrangement enables the counter-shaft, and therefore the spindle, to be reversed when a "tapping" apparatus is used on the machine.

Motion is transmitted to the machine shaft by means of two equal cone pulleys on the counter and machine shafts respectively, and from that to the spindle through the two machine-cut bevel wheels.

When using drills greater than $\frac{3}{4}$″ diameter, the wheels on the back shaft are placed in gear with those on the machine shaft so that the speed of the latter is less than that of the pulley in the ratio of "product of diameters of pinions" to "product of diameters of wheels." With the counter-shaft making 330 revolutions per minute, the speed of the drill spindle can be varied from 340 to 21 revolutions per minute—a sufficiently large variation for any ordinary work.

The feed of the drill spindle may be effected automatically or by hand. The upper part of the spindle is reduced in diameter to pass through a tubular rack. The worm wheel on the rack pinion shaft is rotated by the worm on the vertical feed shaft, which latter receives its motion through a worm and wheel from the horizontal feed shaft connected by cone pulleys to the driving shaft. By varying the position of the belt on the feed pulleys, the feed can be varied from 0·01″ to 0·005″ per revolution of spindle, or from 100 to 200 revolutions per inch of feed.

If, however, a hand feed is desired, the horizontal worm wheel, which is not keyed to the vertical feed shaft, is slackened back from the friction plate immediately above it by turning the disc below the hand wheel. The worm wheel is then loose on the shaft, to which motion may now be given through the hand wheel.

For the rapid adjustment of the spindle the vertical worm is thrown out of gear with the wheel—as shown in the drawing—and the balance lever moved by the rod fixed at right angles to its length.

It will be seen that the horizontal table is fixed to the vertical slide by two short bolts, fitting in **T** slots, and a long bolt which acts as a centre when it is necessary to swivel the table round to permit of the drilling of several holes in the work without readjustment on the table. The vertical adjustment of the table is effected by worm and pinion and rack gearing.

In order that the machine may run steadily without being bolted down to the floor, the frame is fixed to a base plate of **U** shape having a large bearing area.

For calculations and more detailed descriptions of the parts, see the notes to Plates III., IV., and V.

Plate II.

MACHINE FRAME.

The frame is a single casting of $\frac{5}{8}$″ metal, except at those parts which are to act as supports for shafts, &c. Its base is planed and secured to the base plate by four $\frac{7}{8}$″ set screws.

The vertical surface over which the table slide moves consists of two planed strips, each $2\frac{1}{2}$″ wide, and bevelled at the outer edge to an angle of 50°. Into a recess midway between them the table rack is fixed by two $\frac{1}{2}$″ set screws. (See Plate V. for horizontal section of frame showing the rack.)

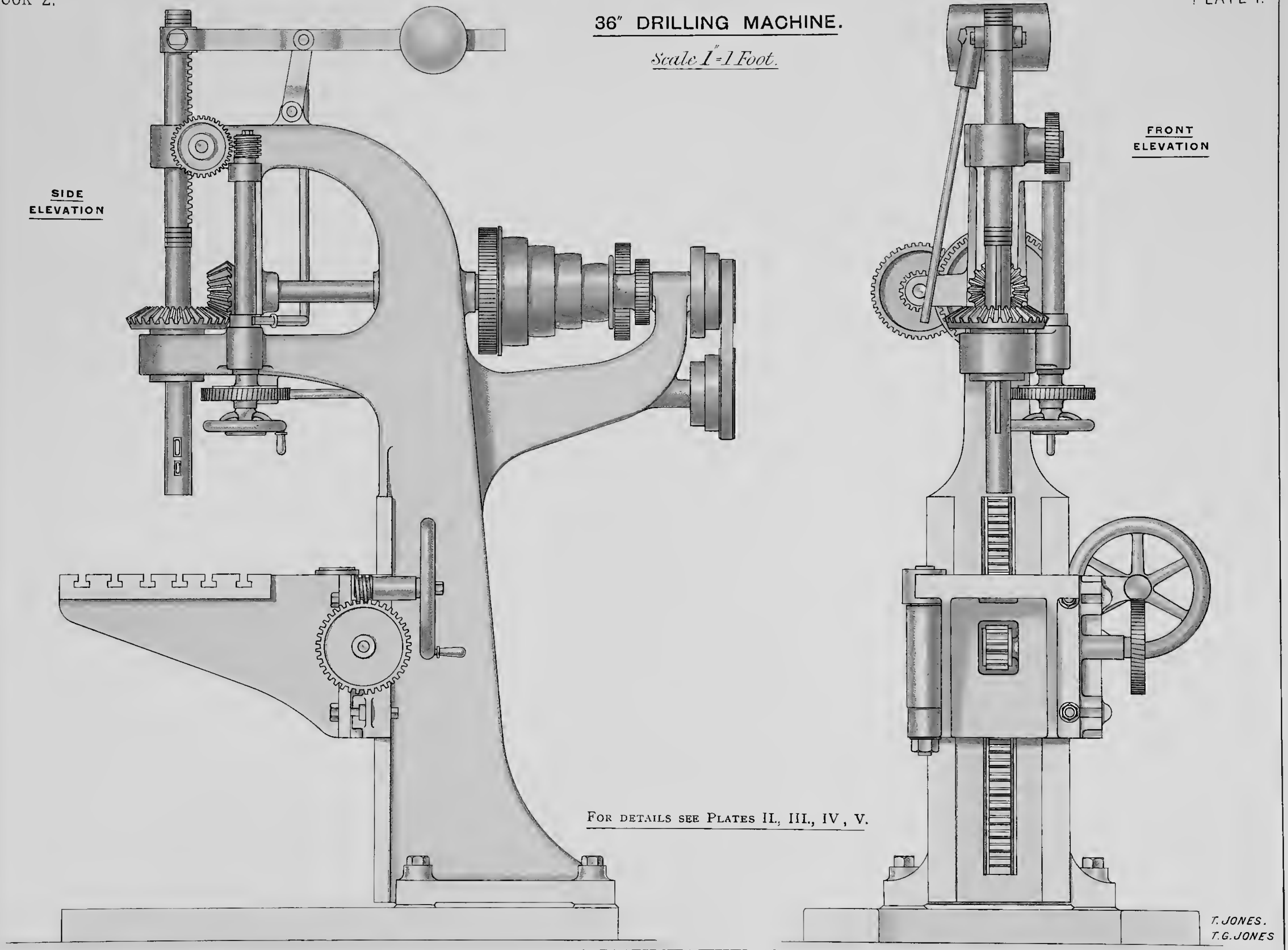
The two portions, through which the vertical spindle passes, are bored out, one to receive the tubular rack, and the other the cast-iron bush for the larger bevel wheel. The former is also bored horizontally to receive the rack pinion.

The driving shaft is supported at its outer end by the large curved arm, and at the other end by a vertical bar near the spindle bossed out to afford sufficient bearing area.

On the frame projections or arms are cast for the supporting of the back shaft, the vertical feed shaft and the balance lever link, and also the horizontal feed and rack pinion shafts.

36″ DRILLING MACHINE.

Scale 1″ = 1 Foot.



FOR DETAILS SEE PLATES II., III., IV, V.

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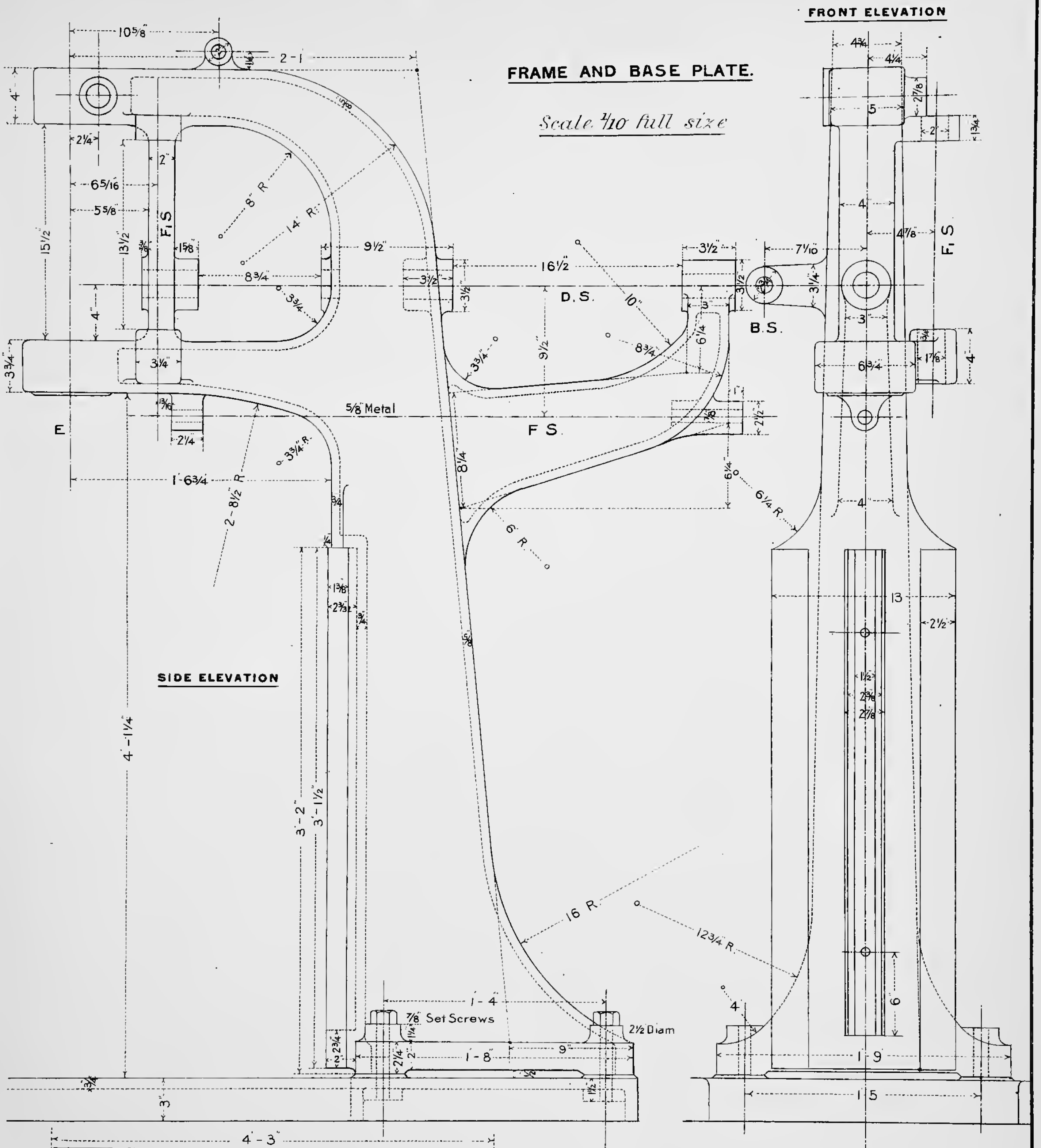
36" DRILLING MACHINE.

FRAME AND BASE PLATE.

Scale 1/10 full size



HALF-PLAN OF BASE PLATE.

Scale 3/4 = 1 Foot

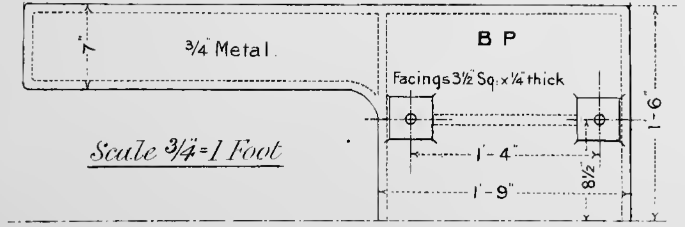


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Plate III.—36″ DRILLING MACHINE.

DRILL SPINDLE.

FIGS. 1, 3, and 4 show the details of the mild steel spindle **E**. At its lower end is a taper hole to receive the shanks which carry the drills of various sizes; the upper portion is turned down to $1\frac{1}{4}''$ diameter to pass through the cast-iron tubular rack **T R**, which is used to give the vertical motion to the spindle. The axial pressure resulting from the process of drilling is received by four hard steel thrust washers (Fig. 3) placed between the end of the rack and the shoulder on the spindle. Lubrication to the washers is effected through a $\frac{1}{4}''$ oil hole passing from the top of the spindle. (See Plate IV. for details of top of spindle).

In order that the spindle may have both vertical and rotary motions, two key-ways are cut in it to receive the keys which are fixed in the boss of the wheel $\mathbf{W_1}$.

CUTTING SPEED OF DRILL.

The circumferential velocity of the drill when cutting wrought-iron and cast-iron should be about 220 inches and 175 inches per minute respectively. The cutting speed for cast-iron is 20 per cent less than that for wrought-iron.

CUTTING SPEEDS FOR WROUGHT-IRON.

Diameter of drill in inches.	Revolutions of drill per minute.	Revolutions per inch of feed.	Diameter of drill in inches.	Revolutions of drill per minute.	Revolutions per inch of feed.
$\frac{1}{4}$	280	200	2	35	100
$\frac{3}{8}$	190	140	$2\frac{1}{4}$	30	100
$\frac{1}{2}$	140	100	$2\frac{1}{2}$	28	100
$\frac{5}{8}$	110	100	$2\frac{3}{4}$	26	100
$\frac{3}{4}$	95	100	3	23	100
$\frac{7}{8}$	80	100	$3\frac{1}{4}$	22	100
1	70	100	$3\frac{1}{2}$	20	100
$1\frac{1}{4}$	55	100	$3\frac{3}{4}$	19	100
$1\frac{1}{2}$	50	100	4	18	100
$1\frac{3}{4}$	40	100	...	...	...

If d = diameter of drill in inches,
n = revolutions of drill per minute,
s = cutting speed in inches,

Then $n = \frac{s}{d\pi}$;

Or, revolutions per minute $= \frac{\text{constant}}{\text{diameter of drill}}$.

For wrought-iron – constant $= \frac{220}{\pi} = 70$.
For cast-iron – constant $= 55$.

By means of the above expression, the accompanying table of speeds for various sizes of drills is calculated.

BEVEL WHEELS $\mathbf{W_1}$ $\mathbf{W_2}$.

These are used to transmit the motion from the horizontal shaft **D S** to the vertical spindle **F S**. In the transmission the speed is reduced in the ratio of 17 to 30. The wheel $\mathbf{W_1}$, through which the spindle passes, has a long conical boss turning in a cast-iron bush, and is held endways by the plate fixed to the end of the boss.

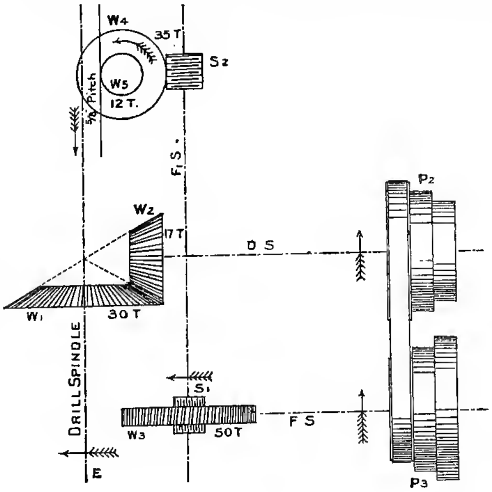
FEED GEAR.

The motion for the automatic feed of the drill is taken from the driving shaft **D S** by means of the small cone pulleys $\mathbf{P_2}$, $\mathbf{P_3}$ (Plate IV.), the worm **S** and wheel $\mathbf{W_3}$, the worm $\mathbf{S_2}$ and wheel $\mathbf{W_4}$, the rack pinion $\mathbf{W_5}$ and the connecting shafts **F S** and $\mathbf{F_1\,S}$.

The vertical feed shaft $\mathbf{F_1\,S}$ has keyed to it the worm $\mathbf{S_2}$, the friction plate **F P** and the hand wheel $\mathbf{H_2\,W}$. The hand wheel has a very small motion along the shaft, so that when the small disc below is turned, the worm wheel $\mathbf{W_3}$, which is loose on the shaft, is jammed against **F P**, and its rotary motion is transmitted to the shaft. The hand feed is effected by turning the hand wheel $\mathbf{H_2\,W}$ when the friction plate and worm wheel are apart.

When the drill is to be moved rapidly to or from the work, the worm $\mathbf{S_2}$ is taken out of gear with the wheel by an eccentric motion. The shaft $\mathbf{F_1\,S}$ passes eccentrically through the cast-iron sleeve **F**, and when the latter is turned through 180°, by moving the handle **H** to the right, the $\frac{3}{8}''$ outward motion of the shaft is sufficient to move the worm out of gear with the wheel.

It will be seen from Fig. 4 that the rack pinion $\mathbf{W_5}$ and its shaft are in one piece, and that one end of the shaft is enlarged to fit the recess made to receive the pinion.



CALCULATION OF FEED.

To determine the maximum feed per revolution of spindle.

For 1 revo. of spindle the driving shaft **DS** makes $\frac{30}{17}$ revolutions.

" " shaft **FS** " $\frac{30}{17} \times \frac{8\frac{1}{2}}{6} = \frac{5}{2}$ revos.

" " " $\mathbf{F_1S}$ " $\frac{5}{2} \times \frac{1}{50} = \frac{1}{20}$ "

" " wheel $\mathbf{W_5}$ " $\frac{1}{20} \times \frac{1}{35}$ "

$\therefore \frac{1}{20 \times 35}$ of circumference of pitch circle of rack pinion = *feed*

$$= \frac{1}{20 \times 35} \times \frac{12}{1} \times \frac{5}{8} = 0{\cdot}0106''.$$

Or, 100 *revolutions of spindle per inch of feed.*

Again, *minimum feed* $= {\cdot}0106 \times \frac{6 \times 6}{8\frac{1}{2} \times 8\frac{1}{2}} = {\cdot}0053''$.

Or 200 *revolutions per inch of feed.*

The intermediate feed corresponds to 140 revolutions per inch of feed.

The feed for cast-iron may be greater than that for wrought-iron.

BOOK 2.

PLATE III.

36" DRILLING MACHINE.

DETAILS OF DRILL SPINDLE, BEVEL WHEELS AND FEED GEAR.

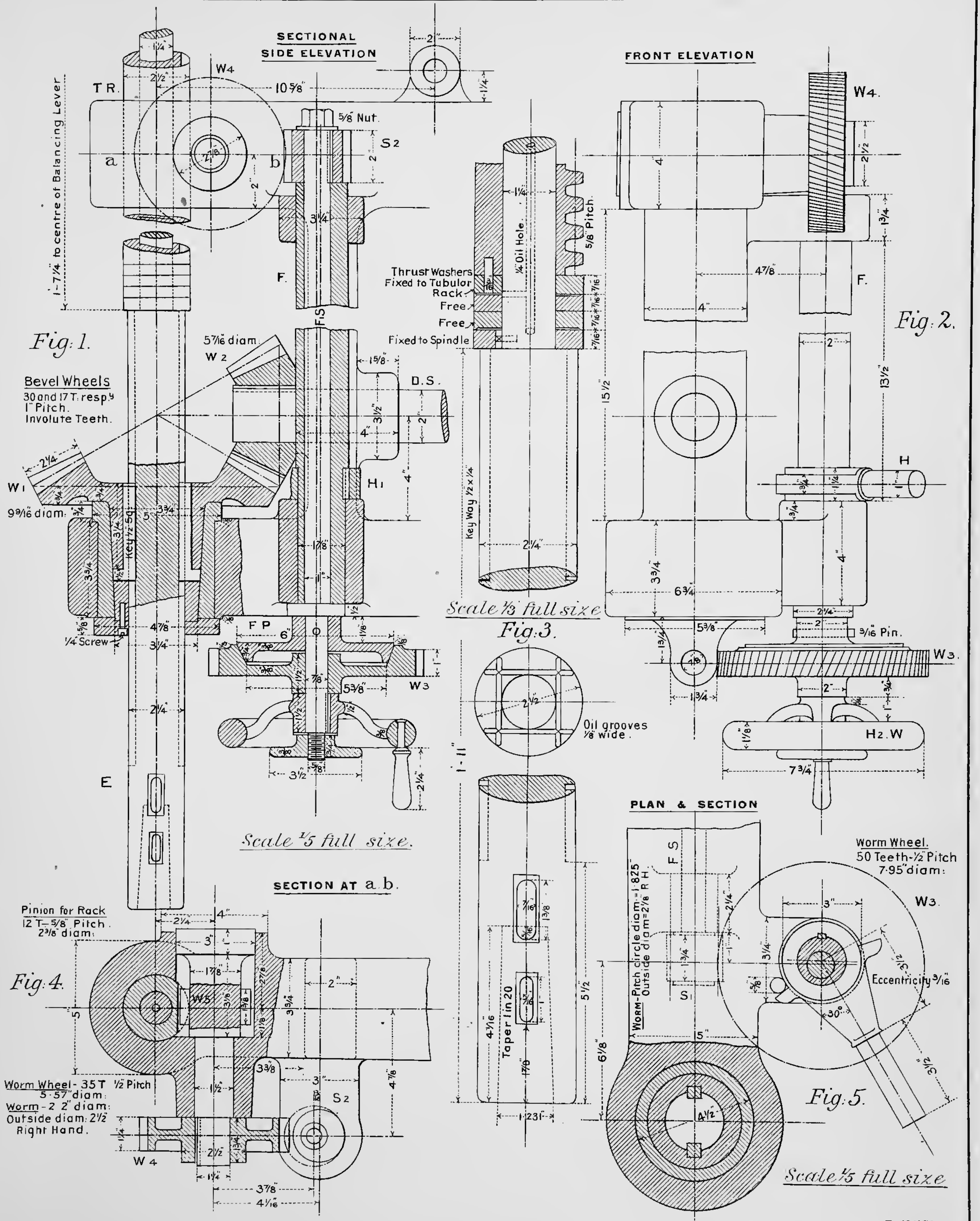


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Plate IV.—36" DRILLING MACHINE.

CONE PULLEY AND DRIVING WHEELS.

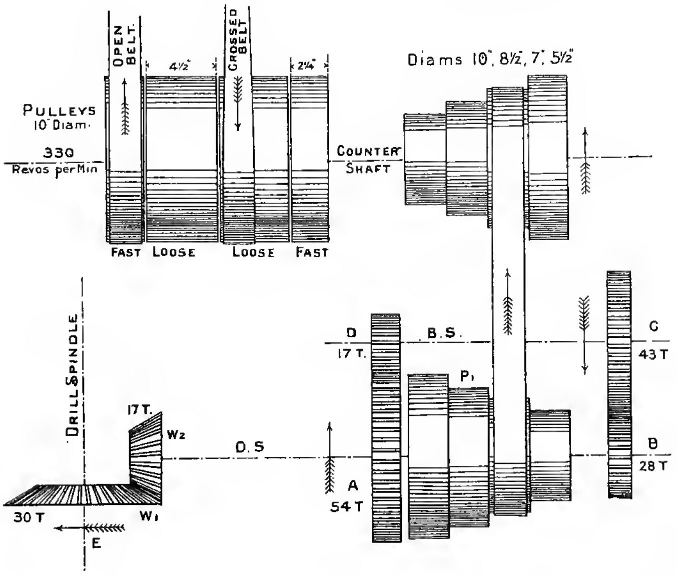
THE power for the driving of the machine is taken from a counter-shaft by means of two equal cone pulleys placed respectively on the counter-shaft and driving-shaft **D S** of the machine. In order that a tapping apparatus may be used, the counter-shaft carries two pairs of fast and loose pulleys, by which arrangement a reversal of motion may be effected for the withdrawal of the tap from the hole.

The cone pulley **P** and the pinion **B** run loose on the shaft, and the wheel **A** is keyed to it. The back shaft **B S**, which carries the pinion **D** and wheel **C**, is supported by two horizontal arms projecting from the side of the frame, and has sufficient end motion to enable the wheels to be put in or out of gear with those on the pulley shaft. To hold the back shaft in either of the two required positions a pin passes through one of the arms, and fits against a semi-circular groove on the shaft. The wheels **D** and **C**, when not used to reduce the speed, are moved to the left, as shown in the drawing; and the pulley **P** is fixed to the wheel **A** by moving outwards a short bolt, carried by the latter, so that its head fits into a recess on the pulley face.

The pinion **B** is fixed to the pulley by two ⅜" cylindrical keys, as shown.

On the driving shaft, outside the supporting bracket, is keyed the first feed cone pulley P_2, which is directly above an equal one P_3, carried by the horizontal feed shaft **F S**.

SPEED OF SPINDLE.



The accompanying diagram shows the general arrangement of the wheels and pulleys for effecting the rotation of the drill spindle.

For clearness the back shaft is shown in the same vertical plane as the driving-shaft and drill spindle.

The counter-shaft makes 330 revolutions per minute: it is required to determine the speed of the spindle for all positions of the belt, with and without back gearing.

NOTE.—Revolutions of spindle = revolutions of $\text{D S} \times \frac{W_2}{W_1}$

1st.—WITHOUT BACK GEARING.

(*a*) Maximum speed $= \frac{330 \times 10}{5\frac{1}{2}} \times \frac{17}{30} = 340$ revolutions per minute.

(*b*) 1st intermediate speed $= \frac{300 \times 8\frac{1}{2}}{7} \times \frac{17}{30} = 227$ „ „ „

(*c*) 2nd „ „ $= \frac{330 \times 7}{8\frac{1}{2}} \times \frac{17}{30} = 154$ „ „ „

(*d*) Minimum „ $= \frac{330 \times 5\frac{1}{2}}{10} \times \frac{17}{30} = 102{\cdot}8$ „ „ „

2nd.—WITH BACK GEARING.

The speed is reduced in the ratio of 1 to $\frac{B \times D}{A \times C}\left[= \frac{28 \times 17}{54 \times 43} = k\right]$

(*a*) Maximum speed $= 340 \times k = 69{\cdot}7$ revolutions per minute.
(*b*) 1st intermediate speed $= 227 \times k = 46{\cdot}5$ „ „ „
(*c*) 2nd „ „ $= 154 \times k = 31{\cdot}5$ „ „ „
(*d*) Minimum „ $= 102{\cdot}8 \times k = 21$ „ „ „

BALANCING LEVER AND WEIGHT FOR SPINDLE.

In order that the spindle may be easily and rapidly moved to and from the work, its top is fitted with a cast-iron collar to which the wrought-iron forked balance lever **B L** is attached. Hardened steel washers are placed between the collar and the circular nuts to receive the rubbing resulting from the collar not rotating with the spindle.

Where the lever is shaped for attachment to the supporting link **L** a rod H_2 is fixed at right angles to **B L**, by means of which the spindle is adjusted for height.

The balance weight weighs about 70lbs.

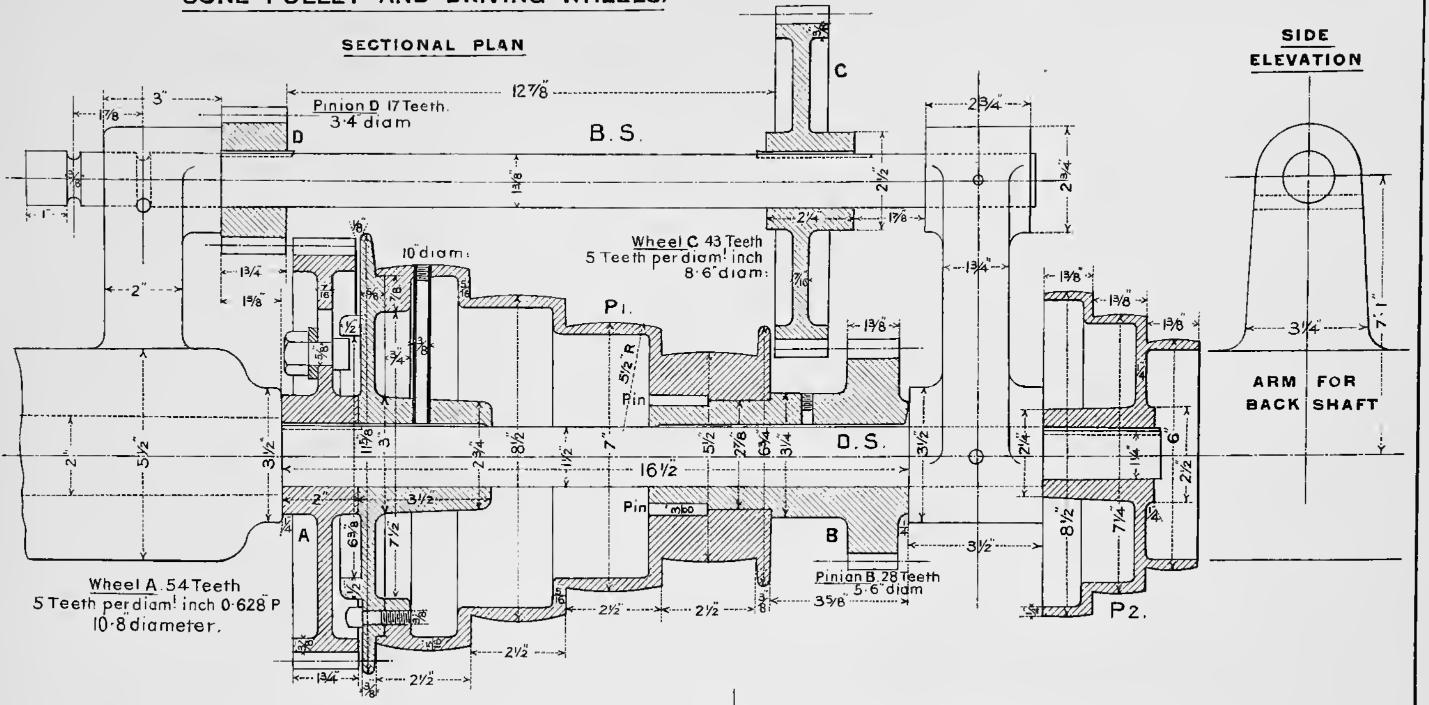
Book 2.

36" DRILLING MACHINE.

PLATE IV.

CONE PULLEY AND DRIVING WHEELS.

Scale 1/5 full size.


SECTIONAL PLAN
Pinion D 17 Teeth. 3·4 diam
D
B.S.
C
12 7/8"
3"
1 7/8
2"
1 3/4"
1 3/8"
10" diam.
Wheel C 43 Teeth 5 Teeth per diam! inch 8·6 diam.
P1.
5 1/2" R
Pin
D.S.
16 1/2
A
B
Wheel A. 54 Teeth 5 Teeth per diam! inch 0·628" P 10·8 diameter.
Pinion B. 28 Teeth 5·6 diam
P2.
2 3/4"
3 1/2"
2 1/2"
SIDE ELEVATION
ARM FOR BACK SHAFT
3 1/4"
7 1"

BALANCING LEVER AND WEIGHT FOR SPINDLE.

Scale 3"=1 Foot.

SUPPORTING LINK FOR LEVER

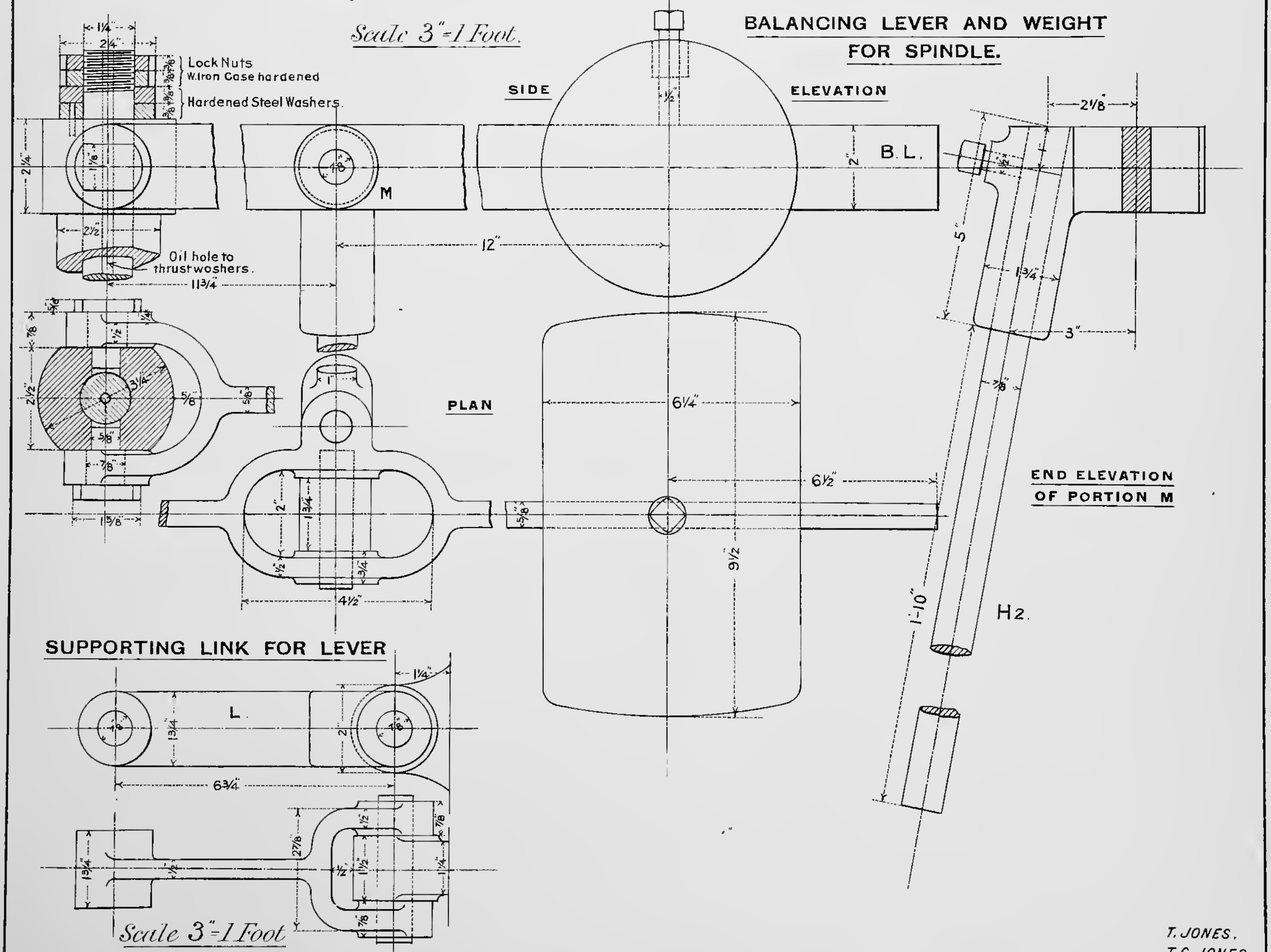


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Plate V.—36″ DRILLING MACHINE.

TABLE WITH LIFTING GEAR.

THE views given on this plate show the table **T**, the slide **T S**, and the gearing by means of which the table is adjusted vertically for the purpose of drilling the piece bolted to it. The **T** slots in the horizontal face of the table afford a convenient means of securing the bolts used in fixing the work.

It will be seen that the table is attached to the slide by means of two short bolts, fitting in **T** slots, and a long bolt **B** which passes through two outer bosses and a middle one cast with the slide and table respectively. This bolt **B** acts as a hinge about which the table can turn. To effect this change of position the nuts on the short bolts are removed, the table swivelled round and afterwards fixed by screwing up the nut on **B**. The head of the bolt fits into a parallel slot cut in the upper boss of the slide, and thus the bolt is prevented from turning.

The slide **T S** is moved along the vertical face of the frame by means of the hand wheel **H W**, the worm $\mathbf{S}_3$ and wheel $\mathbf{W}_6$ and the rack pinion $\mathbf{W}_7$; the last gears with the rack **R** fixed to the machine frame.

The worm is of wrought-iron, case hardened, and is in one piece with its shaft which turns in a long bearing cast with the slide.

Since the worm $\mathbf{S}_3$ is single threaded and the worm wheel $\mathbf{W}_6$ has 43 **T**, one revolution of the hand wheel **H W** will produce $\frac{1}{43}$rd of a revolution of $\mathbf{W}_6$ and therefore of the rack pinion. Hence $\frac{1}{43}$rd of the circumference of the pitch circle of $\mathbf{W}_7$ is the distance through which the table is moved for one revolution of the hand wheel.

$\mathbf{W}_7$ has 8 teeth of $1\frac{1}{4}''$ pitch.

$\therefore \frac{1}{43} \times \frac{8}{1} \times \frac{5}{4} = \frac{10''}{43} \quad = \quad$ say $\frac{1}{4}''$.

The worm and the worm wheel used in this connection have a two-fold advantage; the actual mechanical advantage is great although a large percentage of work is wasted; and since the efficiency is less than 50 per cent, the table will remain in any required position without the application of an external force. (See Plate XXIV. for notes on screw gearing.)

Assume the friction of the gearing and of the slide against the frame to be such as to reduce the efficiency of the mechanism to 30 per cent; then, knowing the weight of the table, &c., which is estimated at 450lbs., the force applied to the hand wheel required to raise a given weight, can be calculated as follows:—

Assume the *weight on the table* to be *500lbs.*

Then when the effort **P** moves through a distance equal to the circumference of the circle described by the handle on the wheel, the weight of (450 + 500) 950lbs. is lifted vertically through $\frac{10''}{43}$.

$$\therefore \mathrm{P}_t \times 2\pi \times 5\tfrac{3}{16} = 950 \times \frac{10}{43}.$$

$$\mathrm{P}_t = 6{\cdot}05\text{lbs.}$$

where P_t = theoretical effort.

Now since efficiency, $\xi = \dfrac{\text{theoretical effort}}{\text{actual effort}}$ required to raise a given weight.

$$\mathrm{P} = \frac{\mathrm{P}_t}{\xi} = \frac{6{\cdot}05}{{\cdot}3} = 20{\cdot}1\text{lbs.}$$

To raise the table itself a force of 9·5lbs. would be required.

To find what force P_1 must be applied to the wheel to *lower* the table, the following expression for efficiency may be used.

$$\xi = \frac{\mathrm{P} \times \mathrm{P}_1}{2\mathrm{P}_1}.$$

where **P** = actual force required to raise the load, and P_1 = force required to maintain the load in position. (In this case P_1 will have a negative value.)

$$0{\cdot}3 = \frac{20{\cdot}1 \times \mathrm{P}_1}{40{\cdot}2} \therefore \mathrm{P}_1 = -\ 8{\cdot}04\text{lbs.}$$

BOOK 2.

PLATE V.

36″ DRILLING MACHINE.

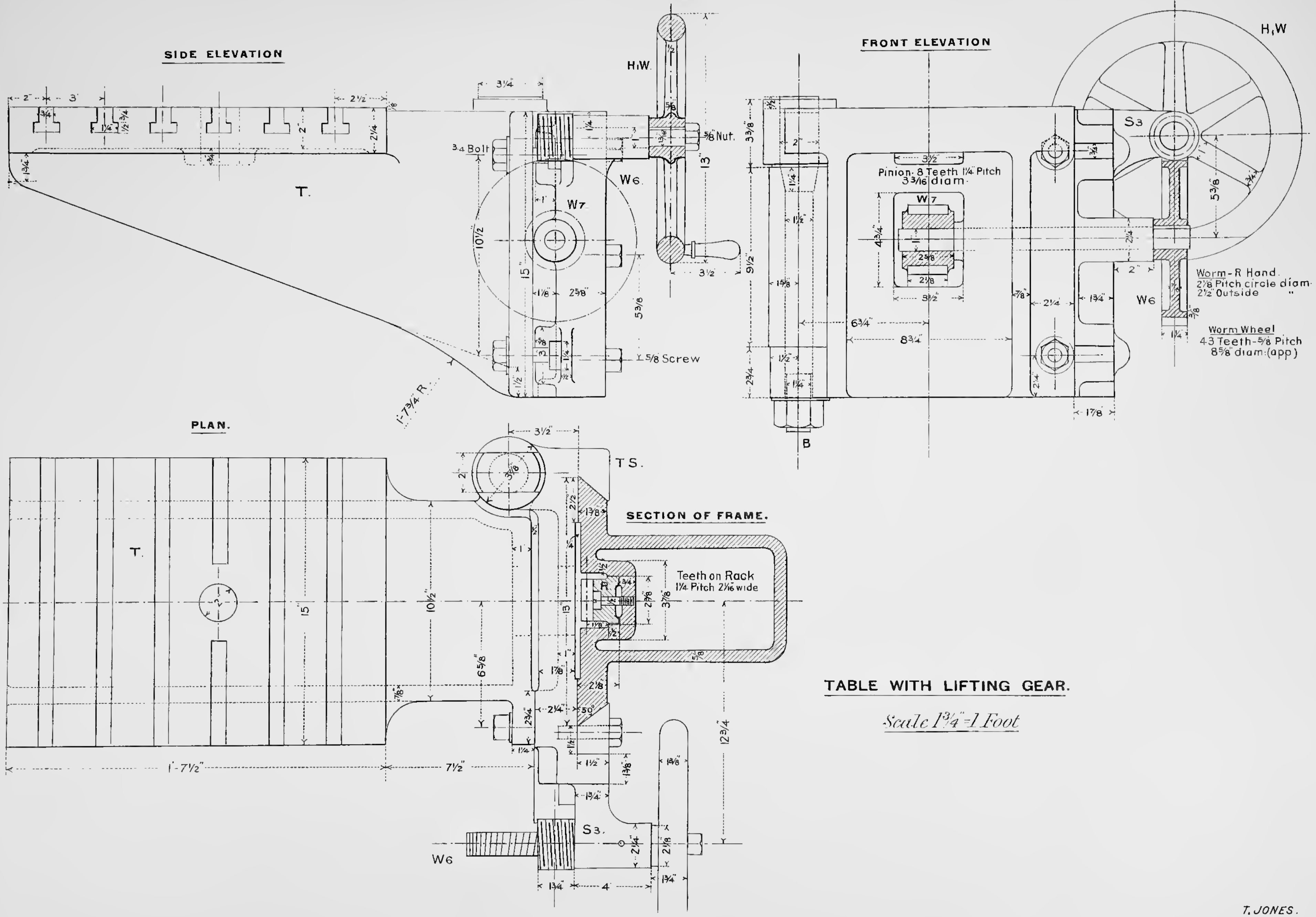

TABLE WITH LIFTING GEAR.

Scale 1¾″ = 1 Foot

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Plate VI.—PLANING MACHINE.

GENERAL DESCRIPTION.—The planing machine, of which details are given on Plates VII. to XI. inclusive, is made by Messrs Hulse and Co., Limited, Manchester, and is capable of planing pieces, whose dimensions do not exceed 2ft. in height and width, and 4ft. in length, at the rate of about three cutting strokes of maximum length per minute.

The power required to drive it when working with full load is about 2 H.P.

The bed **H** is carried on three supports **G**, and is provided with two parallel **V** grooves along which the table **K** moves, actuated by rack and pinion.

To receive the clamping bolts used in holding down the work to be planed, there are **T** grooves 4ft. long on the top of the table.

The gearing consists of the wheels **A, B, C, D, E** and the rack pinion **F**, and is so arranged that the return or non-cutting stroke is performed in $\frac{1}{2\cdot77}$ of the time required for the cutting stroke.

When the belt is on the pulley P_3 the table moves forward, motion being transmitted to the rack pinion through two pairs of wheels, viz., **B, C** and **D, E**; and when on P_1 it returns quickly, since then only the two wheels **A, E** are used in the transmission. With the driving pulley making 112 revolutions per minute the velocities of the table during cutting and returning are 17·7ft. and 49ft. per minute respectively.

To stop the machine the belt is moved on to the loose pulley P_2.

The vertical standards S_1, S_2, bolted to the bed and stayed by the tube **Q**, are required to carry the cross slide **C S** which lies across their front edges. For the vertical adjustment of this slide there are fixed to its two flanges nuts for the vertical screws which hang from the top brackets **U** and are connected with the horizontal shaft **H S** by bevel wheels B_1, B_2. The shaft is actuated by hand, and according to its direction of motion the slide rises or falls.

The pulley bracket **N** carries the pulley shaft and strap fork tackle **O**, and is bolted to the standard S_1. The strap fork bar is connected by the reversing rod **R** with the arm **R A** on the vertical rocking shaft, which, at the end of each stroke, receives an angular motion of 47° from the tumbler shaft. On one edge of the table there are two catches, so adjusted, that before and after the cut one of them engages with the tumbler, carried by the standard S_2, and moves it through an angle of 47° in one or the other direction. At the end of the forward stroke the result of this motion is the displacement of the belt from the pulley P_3 across P_2 to P_1. This same motion of the tumbler may be used to give the horizontal feed to the tool box **T B** along the slide, and the vertical oblique feed to the tool.

By a very ingenious device the automatic horizontal feed may be varied from $\frac{7''}{60}$ to $\frac{1''}{60}$

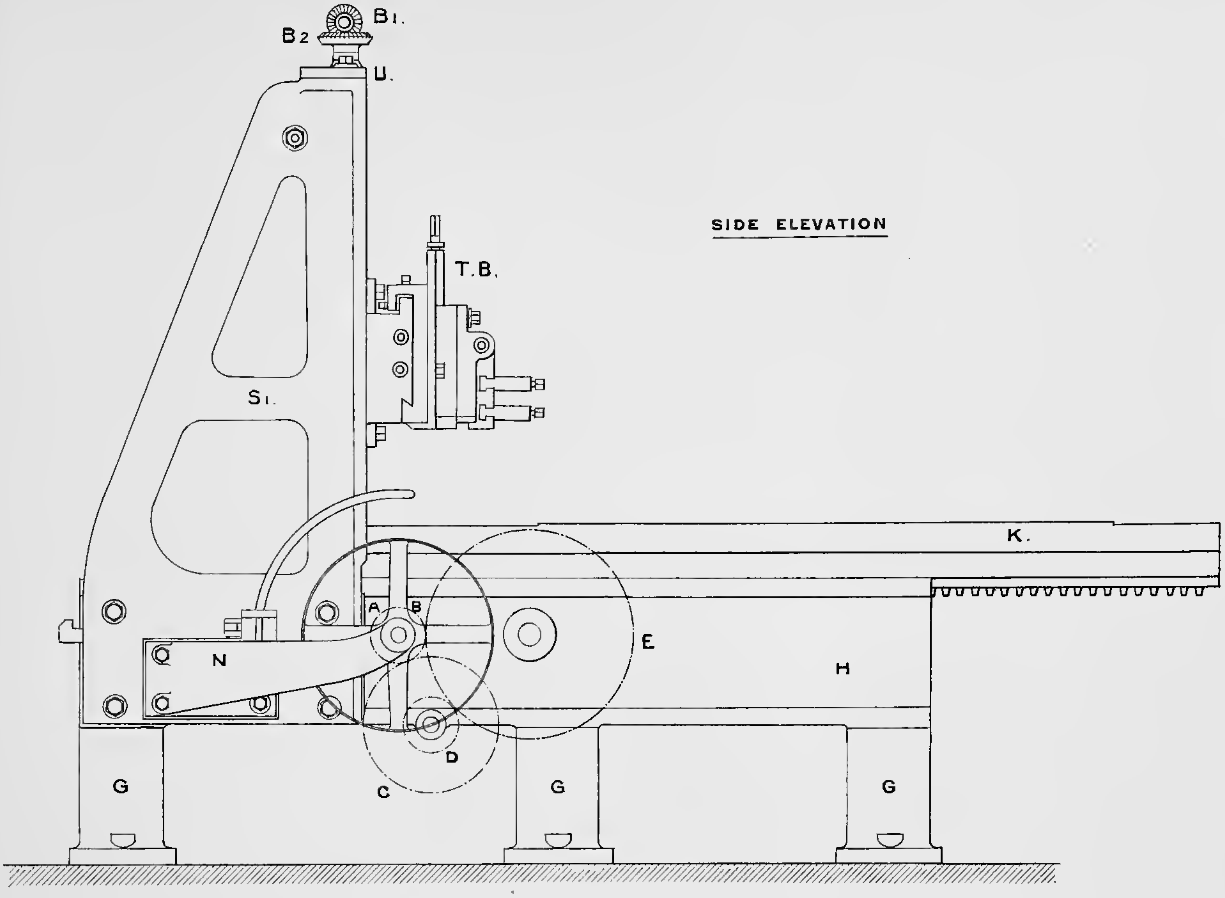
For calculations and more detailed descriptions see the notes to Plates VII. to XI. inclusive.

BOOK 2.

PLATE VI.

PLANING MACHINE, 2′ 0″ × 2′ 0″ × 4′ 0″ STROKE.

Scale ¾″ = 1 Foot.


SIDE ELEVATION

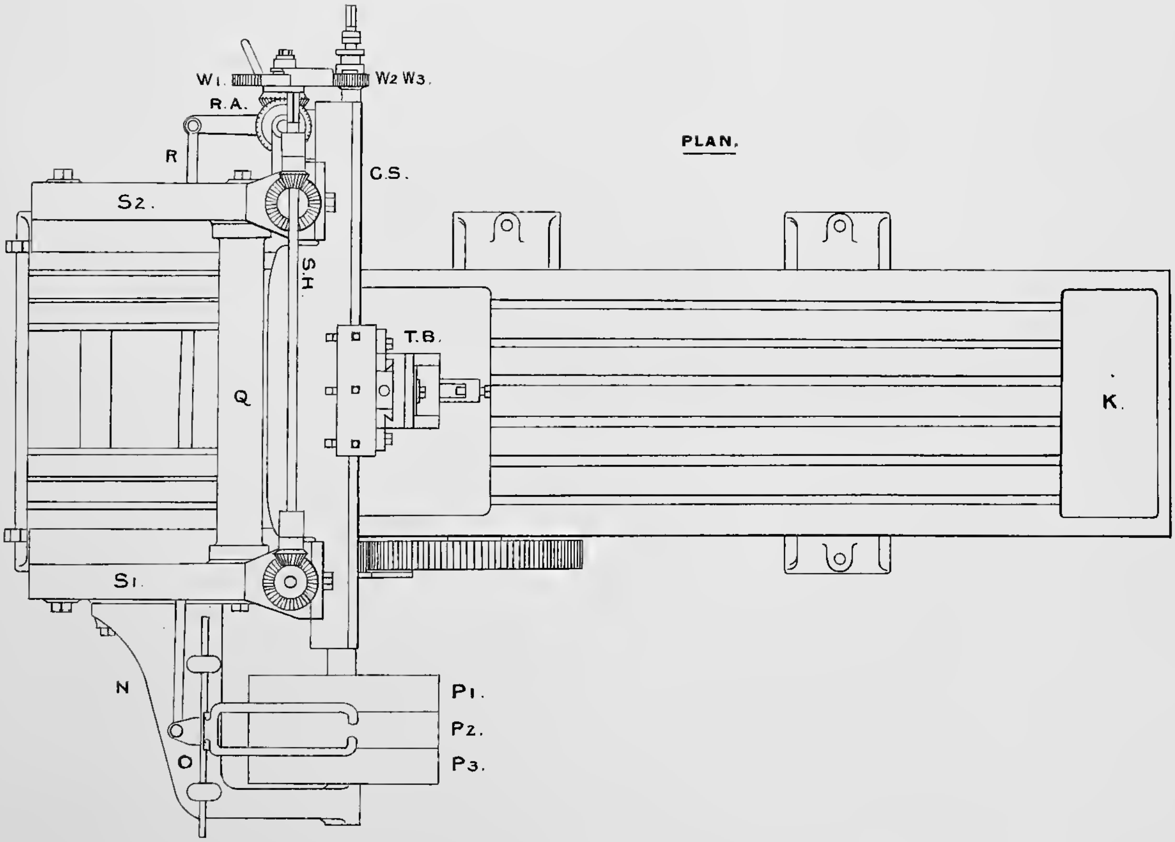

PLAN.

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Plate VII.—PLANING MACHINE.

MACHINE BED.—The cast-iron bed **H** is 6ft. long, and rests on three supports **G**—each one being secured to it by two $\frac{3}{4}''$ bolts or screws. The metal is $\frac{1}{2}''$ thick, and in order to give it sufficient rigidity there are cast with it four cross bars, $4\frac{1}{2}''$ wide, $\frac{1}{2}''$ metal, two of them forming the ends of the bed. To the horizontal flanges of these bars the supports are fixed. On the top are the two parallel **V** grooves by means of which the table is guided in its motion. Cast on the two sides near one end are two facings **J**, 1ft. $11\frac{3}{4}$in. long, each one consisting of two planed strips, 3″ wide, exactly parallel to the length of the bed. (See Plates VIII. and IX. for methods of fixing the standards to the bed.)

The sides are bossed out to support the shafts carrying the driving wheels, **A**, **B**, **C**, **D**, **E** and **F**.

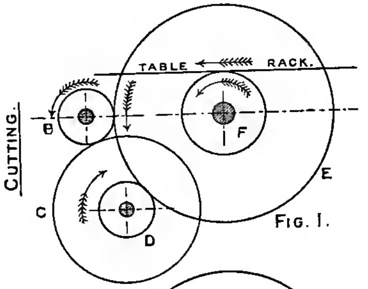

Fig. I.

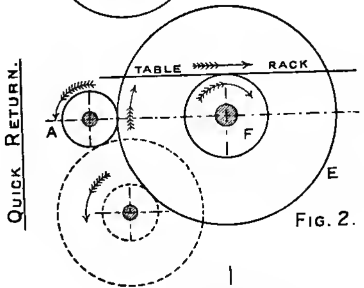

Fig. 2.

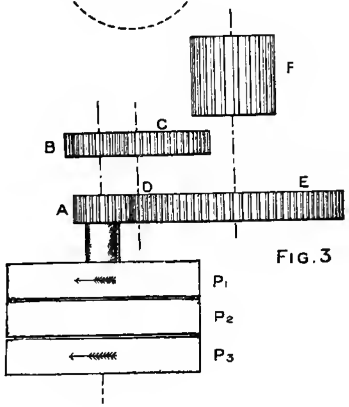

Fig. 3

In the cross section at **X Y** the bar immediately to the right of the section plane is omitted, so that the gearing and bearings beyond it can be clearly shown.

TABLE.—The cast-iron table **K** is 6ft. 5in. long, and for a length of 4ft. its top is provided with **T** grooves to hold the clamping bolts. On its under side are two parallel projections, running the whole length of the table and bevelled to an angle of 120° to fit the **V** grooves of the bed.

Midway between these the cast-iron table rack with teeth of $1\frac{1}{2}''$ pitch is secured to two planed strips by $\frac{1}{2}''$ screws.

It will be seen that on one edge of the table there is a **T** groove into which fit the heads of the bolts used for fixing the two reversing catches.

To ensure exact parallelism between the top of the table and the grooves in the bed the table top is planed by the machine itself.

GEARING.—The toothed wheels, **A**, **B**, **C**, **D**, **E**, **F** and the belt pulleys P_1, P_2, P_3, (for the latter see Plate VIII.) are so arranged that the return stroke is effected in much less time than the cutting stroke.

The pulley shaft has keyed to it the pulley P_3 and the pinion **B**; while the pulleys P_1, P_2, turn freely on it, the former being connected with the pinion **A** by a long cast-iron sleeve with which **A** is cast. The second shaft carries the wheel **C** and pinion **D** (shown in cross section), **C** gearing with **B** and **D** with **E** which also gears with **A**. On the shaft with **E** is the rack pinion **F**, with shrouded teeth, held between bearings so that no end motion is possible.

When the driving belt is on pulley P_3 the motion is transmitted through **B** to **C** and from **D** to **E**, *i.e.*, through two pairs of wheels, each pair reducing the speed. Pinion **A** and pulley P_1 rotate idly in a direction opposite to that of P_3. With the belt on P_2 the machine is stopped; and when it is on P_1 motion passes directly to the driving pinion through **A** and **E**.

In the accompanying diagrams the wheels used in the transmission and those running idly during the cutting and return strokes are indicated in full lines and dotted lines respectively.

The driving pulley makes 112 *revolutions per minute.*

CUTTING STROKE.—See Fig. 1.

The driving and driven wheels are **B**, **D** and **C**, **E** respectively.

$$\frac{\text{Revolutions of pulley}}{\text{Revolutions of pinion F } (N_c)} = \frac{\text{product of numbers of teeth on driven wheels}}{\text{,, \quad ,, \quad driving \quad ,,}} \quad \therefore \frac{112}{N_c} = \frac{C \times E}{B \times D} = \frac{61 \times 68}{22 \times 17}.$$

$$\therefore N_c = 10{\cdot}1 \text{ revolutions per minute.}$$

$$\text{Velocity of table in feet per minute} = N_c \times \text{circumference in feet of pinion F} = 10{\cdot}1 \times 14 \times \frac{1\frac{1}{2}}{12} = 17{\cdot}7\text{ft.} = \text{cutting speed.}$$

RETURN STROKE.—See Fig. 2.

$$\frac{\text{Revolutions of pulley}}{\text{Revolutions of F } (N_r)} = \frac{E}{A} = \frac{68}{17} \therefore N_r = 112 \times \frac{17}{68} = 28 \text{ revolutions per minute.}$$

This rate of rotation corresponds to a table velocity of 49ft. per minute.

$$\frac{\text{Speed of cutting}}{\text{Speed of returning}} = \frac{10{\cdot}1}{28} = \frac{1}{2{\cdot}77} = \frac{\text{time of returning}}{\text{time of cutting}}.$$

[*Continued.*

PLANING MACHINE, 2′ 0″ × 2′ 0″ × 4′ 0″ STROKE.

DETAILS OF BED, TABLE AND DRIVING GEAR.

Scale 2″ = 1 Foot.

SIDE ELEVATION AND SECTION

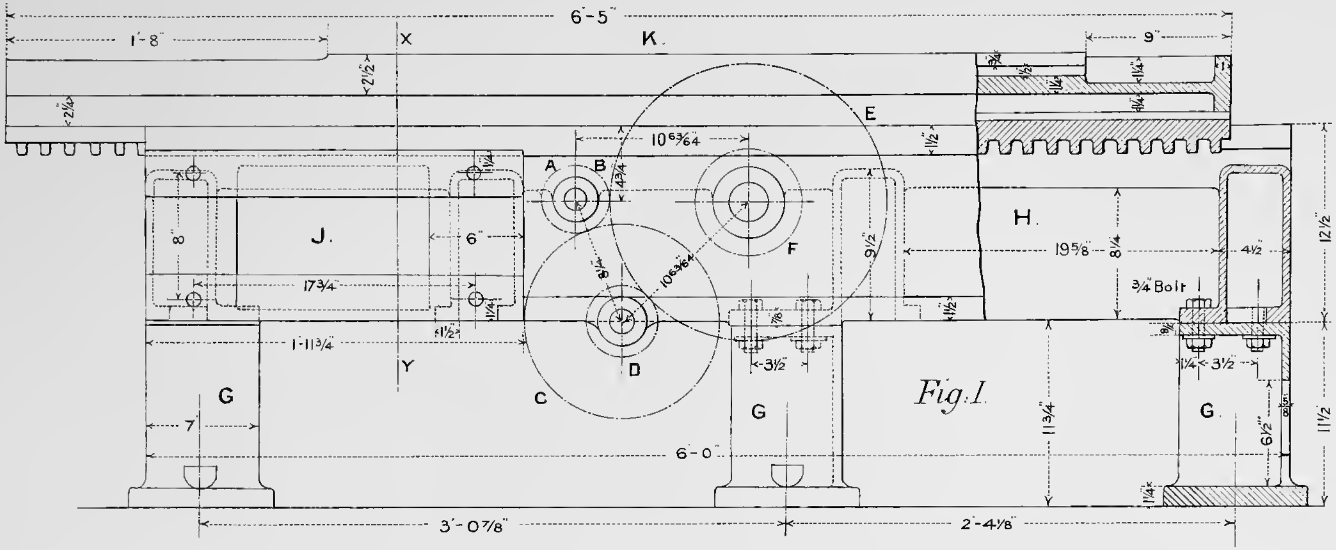

Fig. 1.

SECTION AT X Y

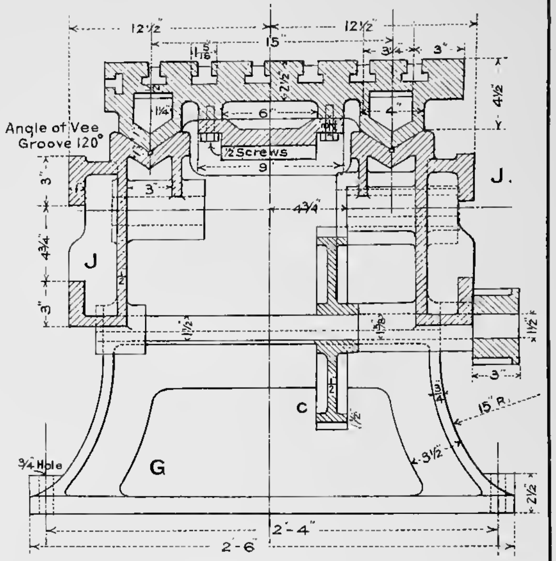

Fig. 2.

PLAN AND SECTION THROUGH A, B, E, F.

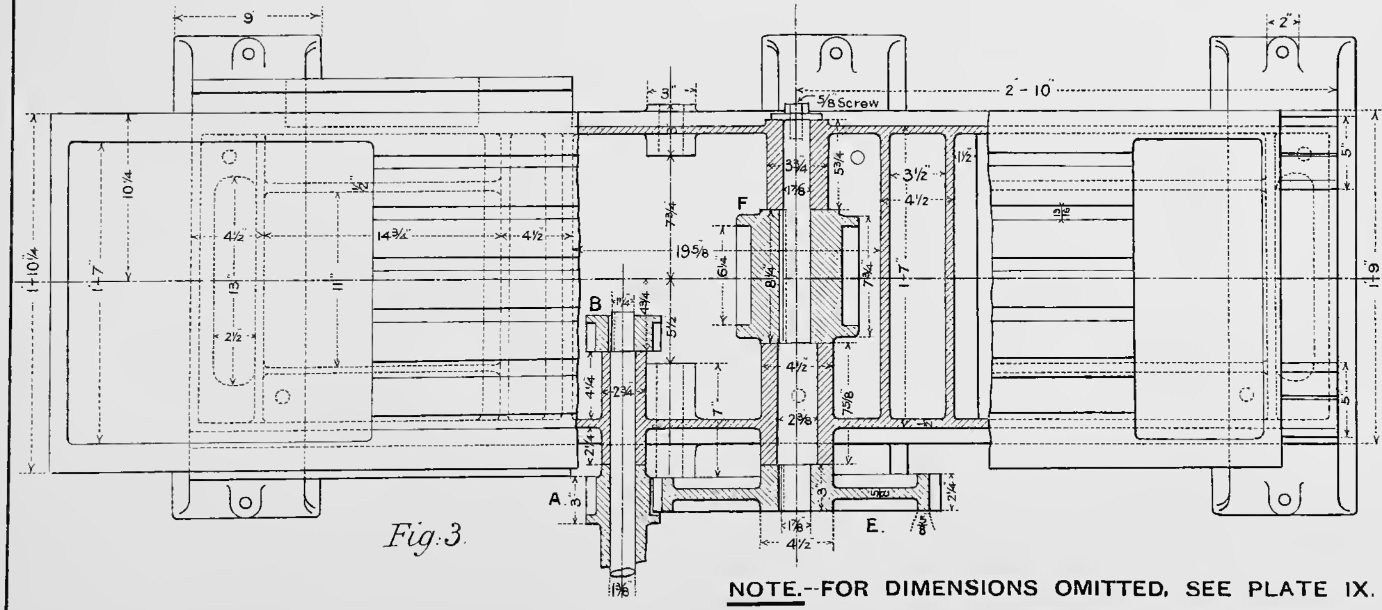

Fig. 3.

LIST OF SPUR WHEELS

WHEEL.	Diameter of Pitch Circle.	Number of Teeth.	Pitch.	Width of Teeth.
A	4 25/64″	17	13/16″	2½″
B	4⅜″	22	⅝″	1⅞″
C	12⅛″	61	⅝″	1¾″
D	4 25/64″	17	13/16″	2½″
E	17 37/64″	68	13/16	2¼″
F	6 11/16″	14	1½″	6¼″
Rack. Teeth, 1½″ Pitch 6″ Wide				

NOTE.—FOR DIMENSIONS OMITTED, SEE PLATE IX.

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PLATE VII.—*Continued.*

To determine the number of maximum cutting strokes per minute—assuming the velocity of the table to be constant throughout the stroke, *i.e.*, neglecting the slipping of the belt due to the inertia of the table.

The time occupied in the traversing of 4ft. at a velocity of 17·7ft. per minute is $\frac{2·77}{3·77}$ of the time 't' minutes for a double stroke.

$$\frac{4}{17·7} \times \frac{3·77}{2·77} = t = 0·308 \text{ min. } \frac{1}{t} = \text{number of cutting strokes per min. } = \frac{1}{·308} = 3\tfrac{1}{4}.$$

Assuming the driving belt to be $2\frac{1}{2}''$ wide, its power, as given by the formula below, is $2\frac{1}{4}$ H.P.

H.P. = ·006 DWR (See notes to Plate XVII., Book I.)

where D = diameter of pulley in feet.

R = revolutions of pulley per minute.

W = width of belt in inches.

The maximum resistance **R** *to cutting* which the machine can overcome, when the efficiency ξ of the mechanism is known, is determined as follows :—

$$R \text{ (lbs.)} \times \text{stroke (ft.)} = HP \times \xi \times 33{,}000 \times \text{time of stroke} \therefore R \times 4 = 2\tfrac{1}{4} \times \xi \times 33{,}000 \times \frac{4}{17·7}.$$

Of the **efficiency of machine tools** little is known, but mention may be made of a note in "Engineering," for June 3rd, 1898, wherein is given the horse-power required to run, when empty and with full load, the various machines used in the Baldwin Locomotive Works. The power admitted of very easy measurement since the machines were electrically driven. For a 36″ planer the horse powers required to run it empty and with full load, were 3·4 and 11·3 respectively. Assuming the wasteful resistances to be independent of the load on the machine the efficiency $= \frac{11·3 - 3·4}{11·3} = 0·7$. In the above example taking $\xi = 0·7$, then R = 2,940 lbs.

Plate VIII.—PLANING MACHINE.

STANDARD AND DRIVING PULLEYS.—Figs. 1, 2 and 3 show the details of the standard **S**$_1$. It is of box section, $\frac{1}{2}''$ metal, and fixed to the side of the bed by four $\frac{3}{4}''$ screws. To relieve these screws from all vertical shearing strain there are cast with the planed face two horizontal 'lips,' one of which rests on the top edge of the facing **J** along its whole length, and the other, made up of two short lengths, each $5\frac{1}{2}''$ long, admits of the use of two keys under the same strip to tighten vertically the connection. (See Plate IX. for additional dimensions, larger section and elevation of this part of the standard.)

On the front of **S**$_1$ is a vertical planed face, $6\frac{1}{2}''$ wide, over which the cross slide **C S** moves for the vertical adjustment of the tool box.

The screws **V S**, one in each standard, supporting the cross slide, are suspended from the brackets **V** secured to the standards as shown in Fig 4 of this and the following plate. They are connected with the horizontal shaft **H S** by bevel wheels **B**$_1$, **B**$_2$, so that its rotation by hand raises or lowers the cross slide—9 revolutions being required to raise it one inch.

The pulley bracket **N**, fixed to the standard, carries one end of the pulley shaft, and also the strap fork tackle **O**. It is of **Γ** section, $\frac{1}{2}''$ thick. On the shaft are three pulleys **P**$_1$, **P**$_2$, **P**$_3$; **P**$_3$ is keyed to it and **P**$_1$, **P**$_2$ run loose, the former being connected by a long sleeve to the pinion **A**.

The slide bar, to which the strap fork is fixed (see Fig. 5), moves through two blocks cast with the bracket, and is actuated either backwards or forwards at the end of every stroke of the table by the reversing rod **R**, which passes through the standards and bed to the other side where it is connected with the reversing arm **R A**.

P$_3$, **P**$_1$ are the driving pulleys for the cutting and return strokes respectively, and with the belt on either the other rotates idly. During the cutting stroke, when the driving pulley **P**$_3$ is making 112 revolutions per minute, **P**$_1$ makes 40·4 revolutions; while with **P**$_1$ driving, **P**$_3$ makes 310·5 revolutions per minute.

The hollow cast-iron stay **Q**, serving to stiffen the two standards, is held in position by a $\frac{3}{4}''$ screwed rod and nuts.

PLANING MACHINE, 2' 0" × 2' 0" × 4' 0" STROKE.

DETAILS OF STANDARD AND DRIVING PULLEYS, &c.

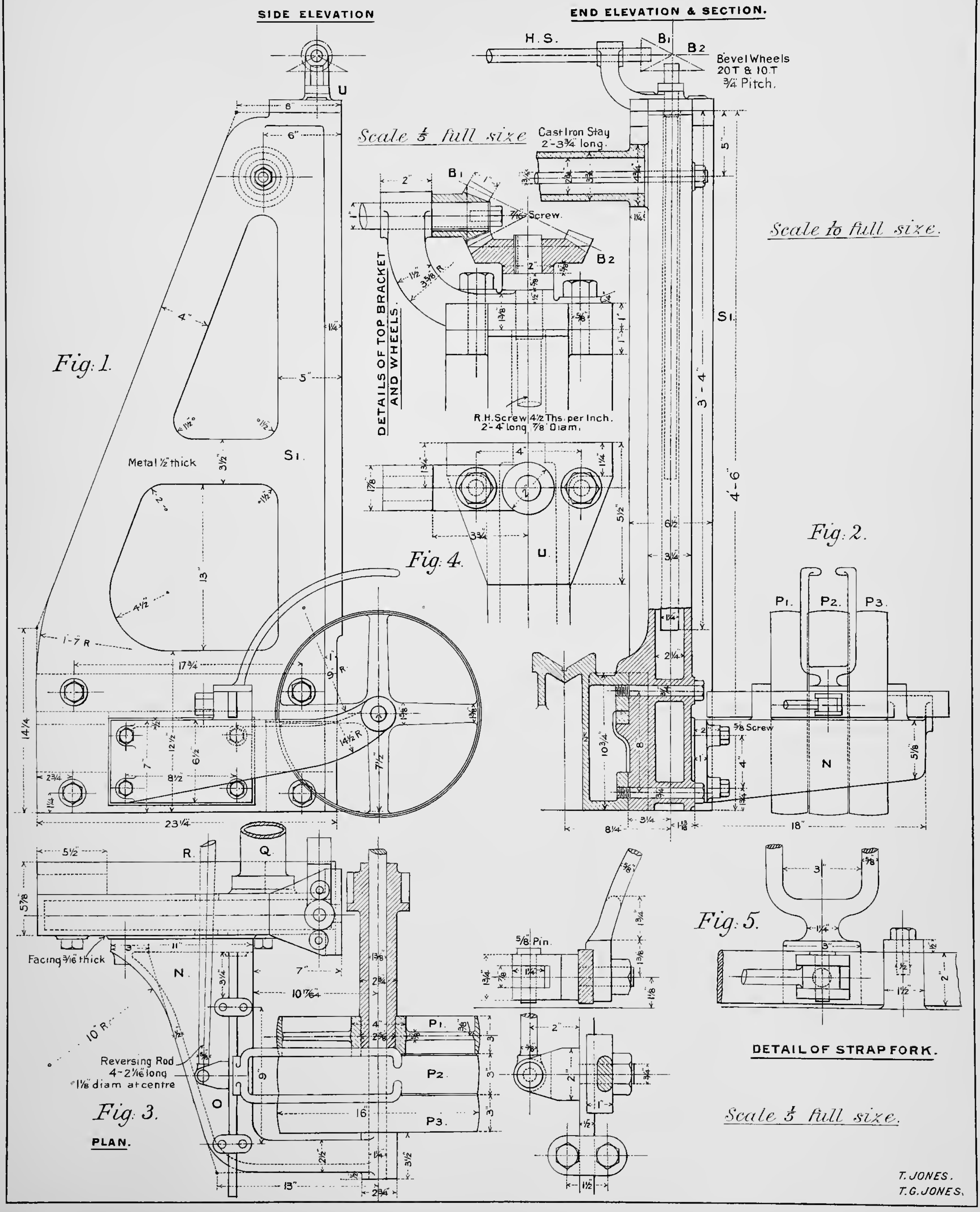

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Plate IX.—PLANING MACHINE.

REVERSING GEAR.—Of the standard S_2 only those details in which it differs from the other standard S_1 are shown here.

Passing through it, on a level with the top of the bed, is the tumbler shaft, which carries at one end the tumbler **T** and at the other one of a pair of mitre wheels M_1, M_2, used in transmitting the intermittent motion of the tumbler to the vertical rocking shaft $F\,S_1$. It will be seen that this shaft is supported at the top by a horizontal arm cast with the top bracket **U**, and below by another one on the standard immediately above the reversing arm **R A**.

The two catches R_1, R_2 (Fig. 5), are so adjusted on the side of the table that when the cut is finished the latter R_2 presses against the shorter arm of the tumbler, when in the position indicated in dotted lines, and moves it through an angle of 47° before passing over. Although towards the end of the contact the driving belt is not on the pulley P_3, the momentum of the table and its load is sufficient to effect completely the reversal of motion by moving the belt over the loose pulley P_2 to P_1.

The position of the tumbler shown in full lines in the drawing is that during the return stroke, and corresponds with the given position of the reversing arm.

Near the end of the quick return stroke the catch R_1 presses against the longer arm of **T** and moves it through an equal angle but in the opposite direction.

In order that the catches may always act upon the right arms, they are made of unequal thicknesses, and the arms placed in parallel planes. It will be noticed that the under-side of R_1 is recessed to permit it to pass over the shorter arm.

Since mitre wheels are used to connect the tumbler and vertical shafts, their angular motions are equal, and the length of the arm **R A** must be determined so that an angular displacement of 47° produces a motion of 6″ of the strap fork.

The vertical shaft is so connected with the cross slide that its motion serves to effect both the horizontal and vertical feeds of the tool.

The handle above the mitre wheels is used for starting and stopping the machine.

The tumbler shaft, the horizontal and vertical shafts, and the vertical screws are made of mild steel; the tumbler, catches, reversing arm and rod, of wrought-iron.

PLANING MACHINE, 2' 0" × 2' 0" × 4' 0" STROKE.

DETAILS OF REVERSING GEAR.

Scale 1/5 full size.

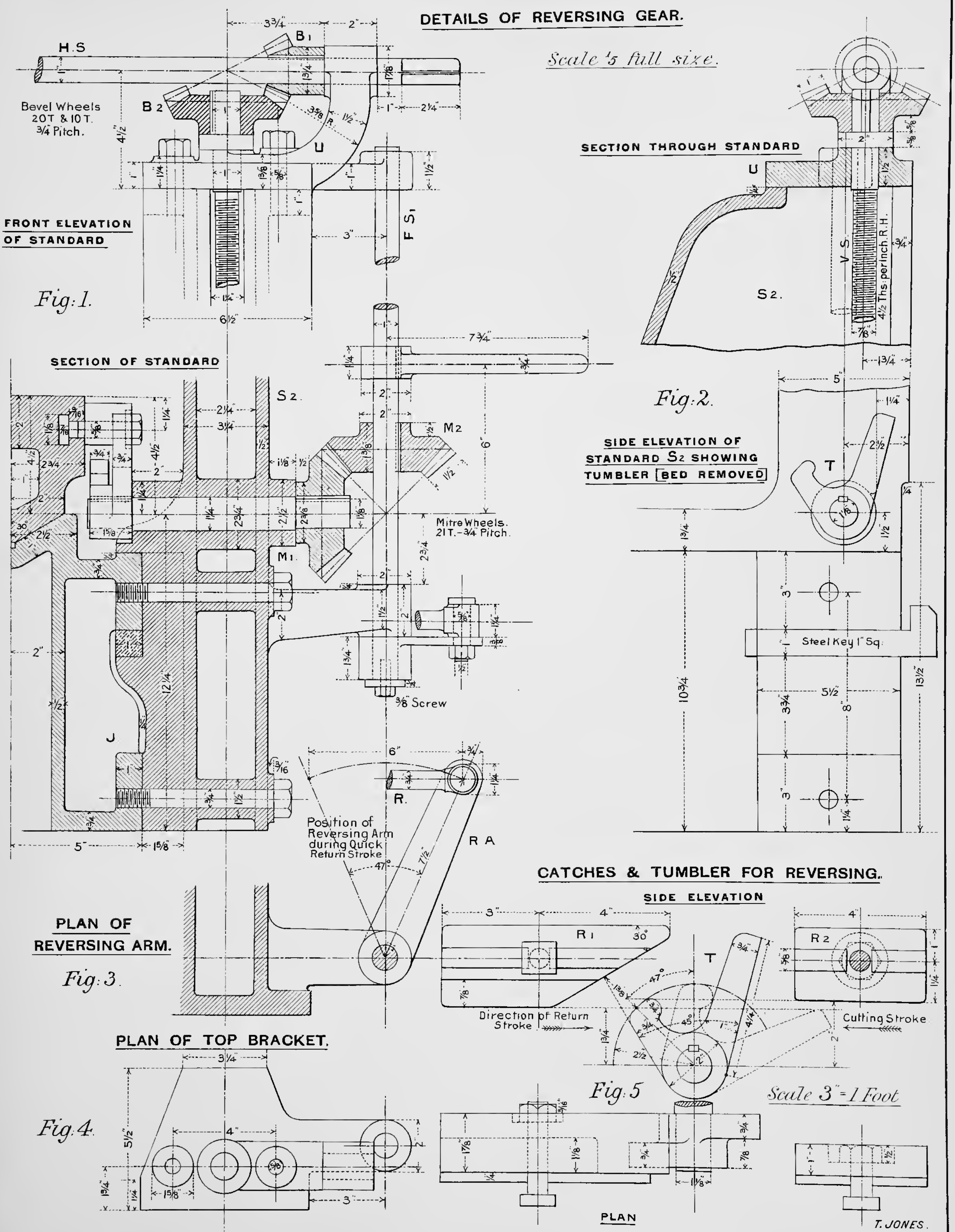

Fig: 1.

Fig: 2.

Fig: 3.

Fig. 4.

Fig. 5

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Plate X.—PLANING MACHINE.

CROSS SLIDE.—The cast-iron cross slide **C S** is held horizontally against the vertical fronts of the standards by four blocks, two secured to each flange of the slide by $\frac{3}{4}''$ screws, so that they are compelled to move along the $1\frac{1}{4}''$ slots in the standards. The two upper blocks form nuts for the vertical screws **V S** which support the slide ; the screws, by their equal and simultaneous rotations, raise or lower the ends of the slide equal distances, and thus keep it horizontal.

It has been observed before that these screws are connected by bevel wheels to the horizontal shaft **H S**. The plain holes in the lower blocks enable the adjusting screws to pass through them when the slide is in a high position.

The front of the slide, over which the tool box moves, consists of two planed strips, the outer edge of the top one being square and that of the lower one bevelled to an angle of 45°.

At the ends are supported the left-hand screw $\mathbf{FS_2}$—for the horizontal traverse of the tool box—and the shaft $\mathbf{FS_3}$, which is required to transmit the motion of the clutch $\mathbf{K_1}$ on its end to the vertical feed screw of the tool box.

During the cutting stroke the slide is a beam fixed at the two ends with the weight or force due to the pressure on the tool acting at some intermediate part ; to render it unyielding the portion between the standards is stiffened by means of a curved back of box section, as shown in the plan.

FEED MOTION FOR TOOL BOX.—Fixed to the back of the cross slide is a bracket carrying a pair of mitre wheels $\mathbf{M_3}$, $\mathbf{M_4}$, by means of which the motion of the vertical shaft is transmitted to the large ratchet wheel $\mathbf{W_1}$. The wheel $\mathbf{M_3}$ carries a feather key which slides in a $\frac{1}{4}''$ key-way in the shaft, and $\mathbf{M_4}$ turns freely on a stud formed with the bracket. The boss of the wheel $\mathbf{M_3}$ passes through the bracket, and is held in position by a collar screwed on its end. On the back of the other wheel the pawl lever is fixed by three $\frac{1}{2}''$ screws with counter-sunk heads, and the pawl carried by it engages with the teeth on the ratchet wheel $\mathbf{W_1}$, which is free to turn on the boss of the mitre wheel.

The cover-plate **C P** is secured to the stud by a $\frac{1}{2}''$ set screw, and may be adjusted to cover up completely or partially the teeth traversed by the pawl.

Turning freely on the ends of the horizontal screw $\mathbf{FS_2}$ and shaft $\mathbf{FS_3}$, and in gear with each other, are the pinions $\mathbf{W_3}$, $\mathbf{W_2}$ respectively, the latter also gearing with the ratchet wheel. On the face of each of these wheels are three curved projections, which may be placed in corresponding recesses in the clutch, and thus the motion of the wheel be transmitted to the shaft or screw.

The angular motion (47°) of the pawl lever is constant, so in order to obtain a variable feed gear the cover plate is adjusted to keep the pawl from the teeth during a portion of its travel. When the cover plate is not used the wheel is moved through a distance of 7 teeth ($\frac{47°}{360} \times \frac{60}{1} = 7\frac{5}{6}$ teeth) and this rotation corresponds to $\frac{7}{60} \times \frac{60}{20} = \frac{7}{20}$th of a revolution of each of the wheels $\mathbf{W_2}$, $\mathbf{W_3}$. Hence, when the clutch $\mathbf{K_2}$ is in gear with $\mathbf{W_3}$ the tool box moves through $[\frac{7}{20} \times \text{pitch of screw} = \frac{7}{20} \times \frac{1}{3}]$ $\frac{7}{60}''$ at the end of the return stroke. This is the maximum horizontal feed.

With the clutch $\mathbf{K_1}$ engaging with the wheel $\mathbf{W_2}$ the corresponding vertical feed of the tool is $\frac{7}{20}$ of $\frac{1}{4}'' = \frac{7}{80}''$.

When the cover plate is adjusted to cover up 1, 2, 3, 4, 5, 6 teeth, the horizontal feeds are $[\frac{6}{60}'', \frac{5}{60}'', \frac{4}{60}'', \frac{3}{60}'', \frac{2}{60}'', \frac{1}{60}'']$ $\frac{1}{10}'', \frac{1}{12}'', \frac{1}{15}'', \frac{1}{20}'', \frac{1}{30}'', \frac{1}{60}''$ respectively.

The vertical feed is less than the horizontal feed in the ratio of 3 to 4, since the screws for the respective feeds are of $\frac{1}{3}''$ and $\frac{1}{4}''$ pitches.

During the return stroke the pawl lever is in the position indicated in Fig. 2, and on the reversal of motion it moves forward and feeds the tool if either of the clutches is in gear with its wheel.

At the end of the cutting stroke the pawl slips over the teeth and rim of cover plate to be in readiness for feeding on the next stroke.

The enlarged section of the pawl is given in Fig. 6.

PLANING MACHINE, 2′ 0″ × 2′ 0″ × 4′ 0″ STROKE.

DETAILS OF CROSS SLIDE.

Scale 1½″ = 1 Foot.

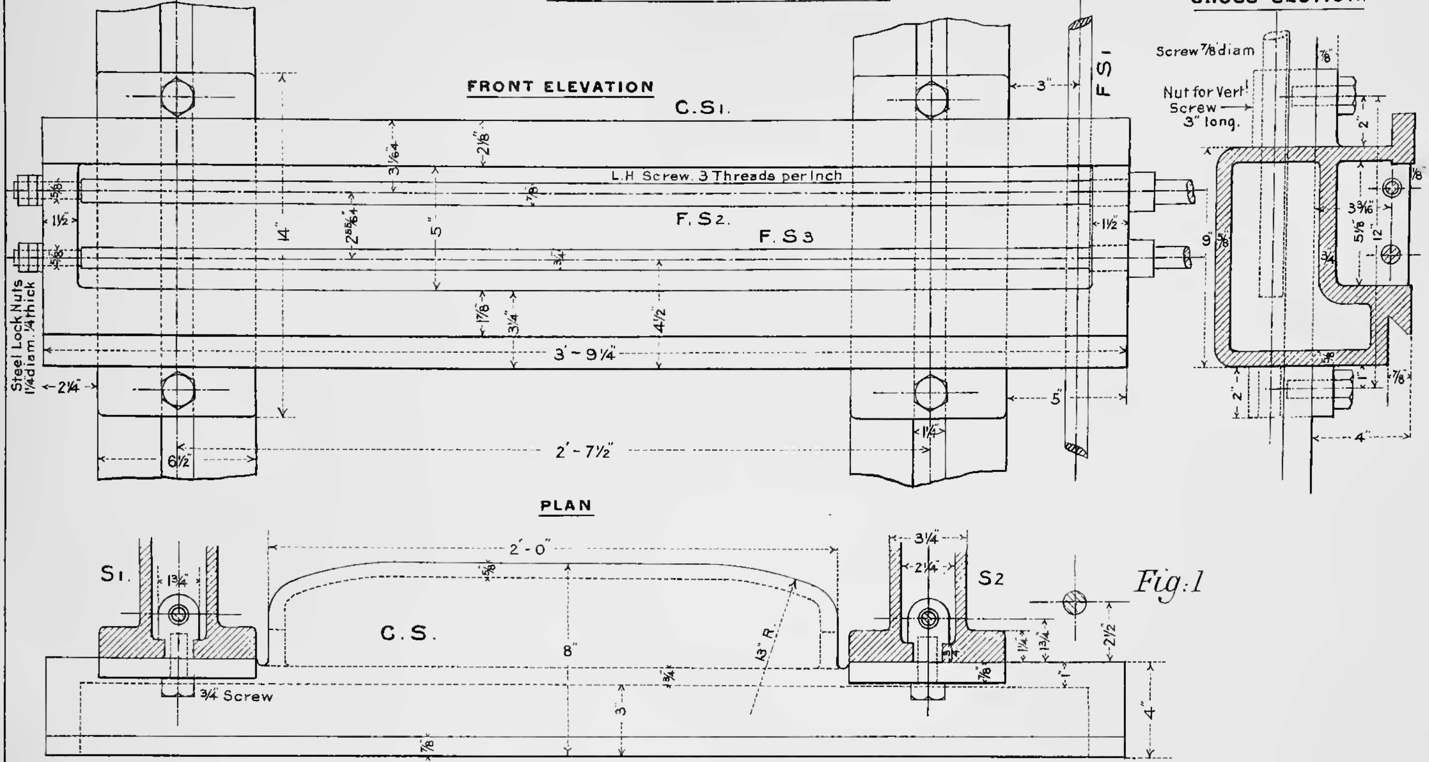

Fig: 1

FEED MOTION FOR TOOL BOX.

Scale ⅕ full size.

SIDE ELEVATION

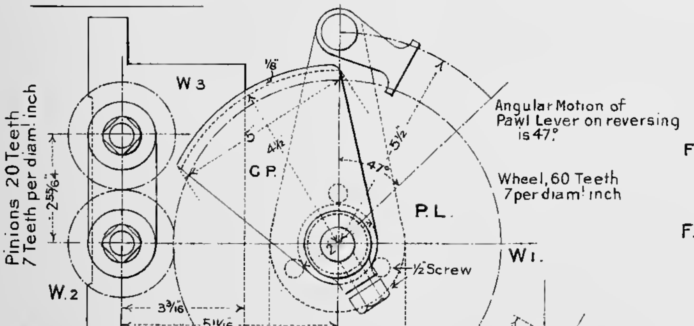
W3
W.2
W1.
G.P.
P.L.
Pinions 20 Teeth 7 Teeth per diam! inch
Angular Motion of Pawl Lever on reversing is 47°
Wheel, 60 Teeth 7 per diam! inch
½ Screw
3³⁄₁₆
5¹¹⁄₁₆
3½

Fig: 2.

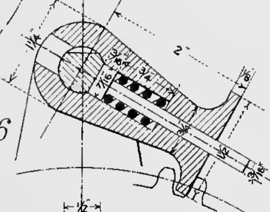

Fig: 6

FRONT ELEVATION

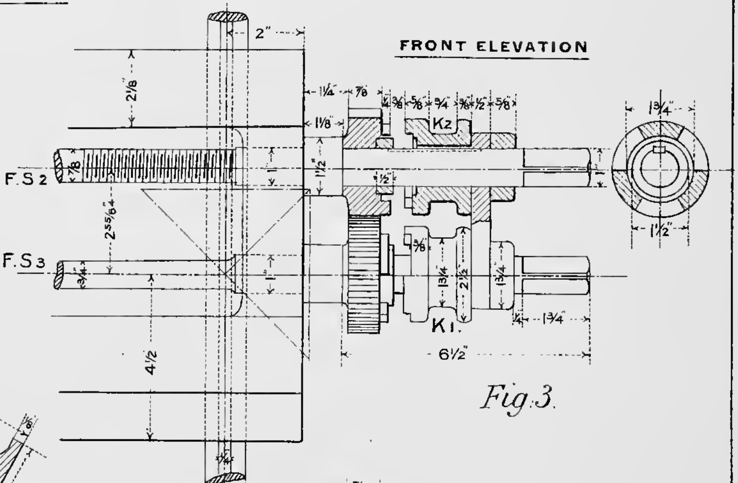

Fig: 3.

SECTION THROUGH *a.b.*

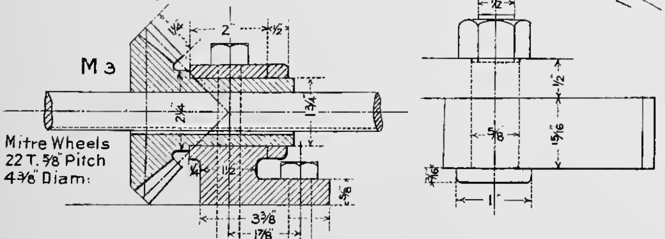

Fig: 5.

PLAN.

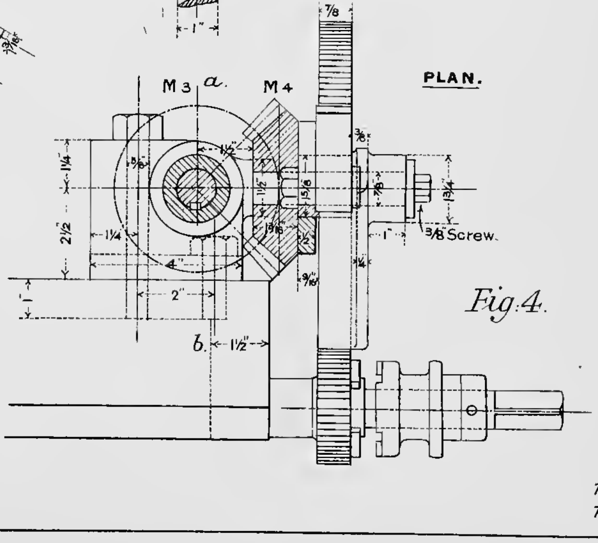

Fig: 4.

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Plate XI.—PLANING MACHINE.

DETAILS OF TOOL BOX.—The tool box is so constructed that the tool can be fed in any direction, viz., horizontally, vertically or obliquely, and also vertically when the tool is at any angle. It consists of three slides Y_1, Y_2, Y_3 and the plate V_1, the last carrying the tool holder plate V_2.

The first slide Y_1 is placed against the front of the cross slide, and is so shaped that it passes over the top edge of the cross slide and is separated from it by a steel strip of **L** section which moves with Y_1 and so receives the vertical wear. By adjusting the vertical and horizontal set screws against it, the slide is held against the vertical face and the bottom bevelled edge respectively of the cross slide. This same slide carries the brass nut for the horizontal feed screw FS_2, and also the double mitre wheel M_6, which, together with wheels M_5, M_7, serves to connect the shaft FS_3, with the vertical screw **X** of the slide Y_2.

The **T** groove in Y_1 being circular the bolts holding the slide Y_2 against it can be moved round, and so the tool placed in any inclined position for planing bevelled edges. Movable along the second slide by the nut and vertical screw is the slide Y_3, whose automatic motion is effected in the manner indicated in Fig. 2. Keyed to the lower end of the screw is a wrought-iron mitre wheel M_7 in gear with the double wheel M_6, whose motion is received from a third wheel M_5 carried by Y_1, and sliding along and rotating with the horizontal shaft FS_3.

When the slide Y_2 is turned into an inclined position, M_7 simply rolls round M_6, for the latter is fixed in the plate at the centre of the groove.

The two parts of the double wheel pass over a pin fitted with a feather key, and are held together by the $\frac{3}{8}''$ screw, whose head presses against the face of the right-hand piece.

The plate V_1, whose inclination relative to the slide carrying it, is limited by the curved slot in it, is provided with two parallel projections, which afford support for the bolt of the tool-holder plate V_2, and serve to prevent any side motion of it. The two steel tool-holders **TH** are so attached to the plate that their set screws, when tightened up, both clamp the tool in the holders and the latter in the plate.

To prevent the grinding of the tool on the work during the return stroke, the plate V_2 is hinged so that it may lift slightly. There is, sometimes, fitted on larger machines an automatic arrangement for lifting the tool clear of the work during the non-cutting stroke.

Hand feed in all directions may be given to the tool.

PLANING MACHINE, 2′ 0″ × 2′ 0″ × 4′ 0″ STROKE.

DETAILS OF TOOL BOX.

Scale 3″ = 1 Foot.

FRONT ELEVATION

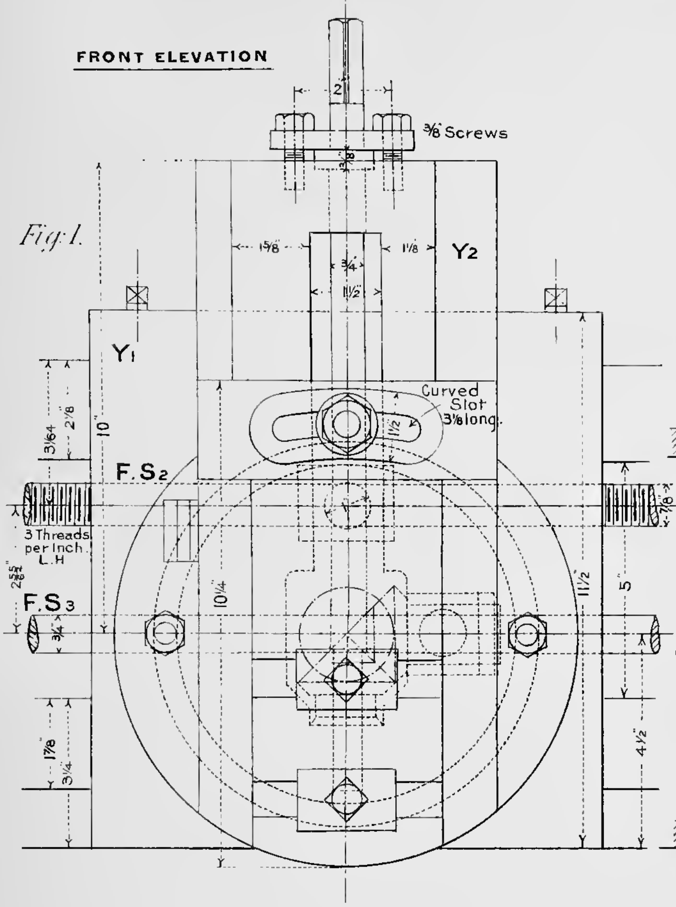


Fig: 1.

SECTIONAL SIDE ELEVATION

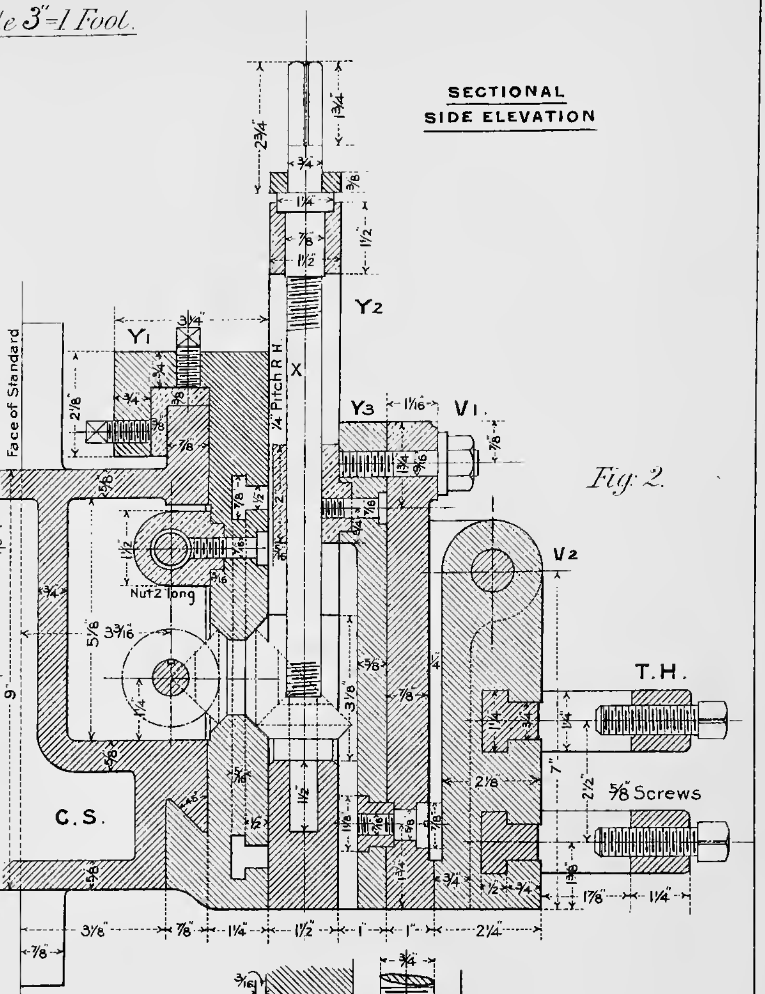


Fig: 2.

PLAN

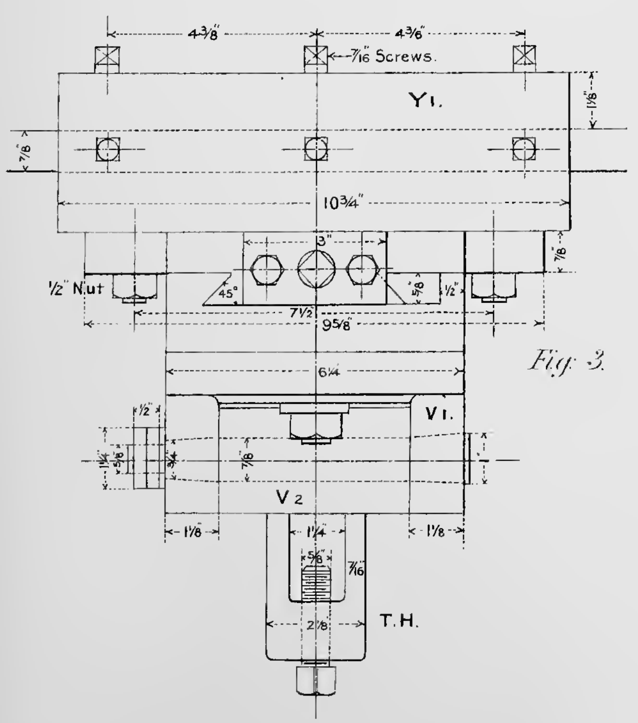
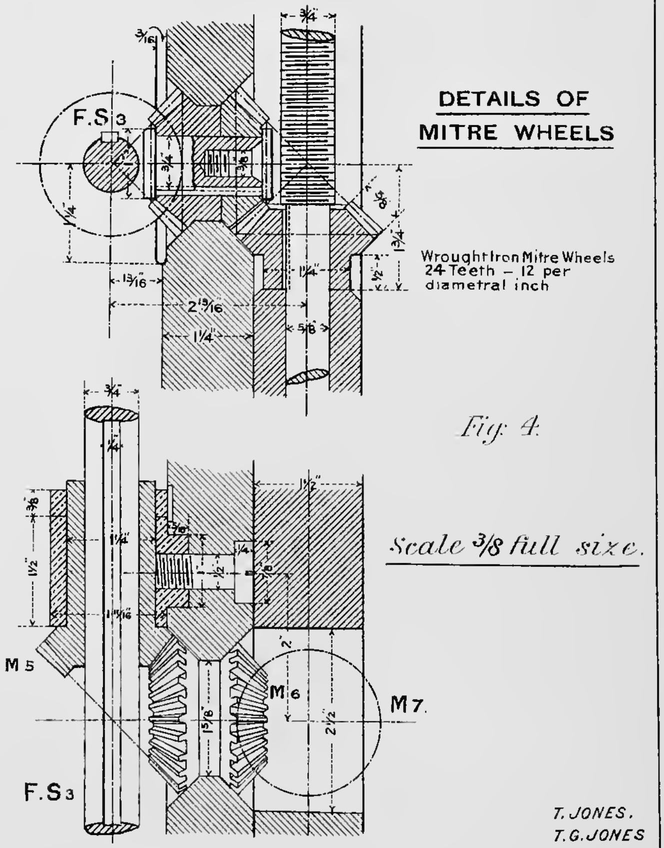


Fig: 3.

DETAILS OF MITRE WHEELS



Wrought Iron Mitre Wheels 24 Teeth – 12 per diametral inch

Fig: 4.

Scale ⅜ full size.

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SLOTTING MACHINE.

Plate XII.

GENERAL DESCRIPTION.—The slotting machine, of which detailed drawings are given on Plates XIII. to XVII. inclusive, is made by Messrs. Smith and Coventry Limited, Manchester, and is capable of producing plane and cylindrical vertical surfaces on pieces not exceeding 9 inches in thickness.

All the parts are carried by a substantial frame of box section.

Power is transmitted to the cone pulley from an equal one on the counter shaft by a $2\frac{3}{4}''$ belt, and passed to the driving shaft of the machine through a pinion and wheel. With the counter-shaft making 100 revolutions per minute the speed of the driving shaft may be 27, 17, or $10\frac{1}{2}$ revolutions per minute, according to the position of the belt.

The ram to which the tool is clamped slides against the vertical face of the frame, and is actuated by a slotted arm whose vibrating motion gives to it a reciprocating motion of continually varying velocity. The arm is driven by a pin carried on the driving plate, which is keyed to the shaft. By adjusting the distance of the pin from the centre of the plate the motion of the free end of the arm, and, therefore of the ram to which it is connected by the forked rod, may be varied from 9 inches to zero. With this particular mechanism the return stroke is performed in less time than the cutting stroke, the ratio of the times of cutting and returning decreasing with the stroke.

The tool has a maximum velocity at the middle of its stroke, and for a stroke of 9″ at the slowest speed of running, the maximum velocity of cutting is 18·7ft. per minute. (See notes to Plate XIV. for calculation.)

The ram is adjusted for height by the hand wheel carried by it, and then locked to the connecting rod by the nut on the front.

The circular table which supports the work has a worm wheel cast to it, and is constructed with a conical base, the latter fitting in a recess on the top of the cross slide, so that it may revolve when a cylindrical surface is being cut. Motions of the table along and across the horizontal frame slide are obtained by attaching it to the saddle and slide.

Three feeds are possible, and all may be effected automatically or by hand. Fixed to a projection near the long bearing for the driving shaft is a feed lever whose end fits into a pear-shaped groove on the face of the wheel, and receives at the end of each return stroke a slight vertical displacement. This motion is transmitted along the several arms and links to the three pawl levers, so that when the pawl carried by any one is in gear with its wheel, the work will be fed forward. Mitre wheels carried by the saddle transmit the intermittent vibrating motion of the horizontal feed shaft to the worm shaft, and the screw of the cross slide. With the pawls in the positions shown in the drawings, the feed of the saddle and cross slide would be effected during the down stroke of the feed pin, while the circular feed would take place on its return stroke.

PLATE XII.—*continued.*

Judging from power tests with the slotting machine, carried out at the Baldwin Locomotive Works, U.S.A., its *efficiency* may be taken at *0·75*. For example—the powers required to drive a 12″ stroke machine when empty and fully loaded were 1·5 and 6·5 H.P. respectively; giving a maximum efficiency (efficiency increases with load) of—

$$\frac{6{\cdot}5 - 1{\cdot}5}{6{\cdot}5} = \frac{5}{6{\cdot}5}, \text{ or 77 per cent.}$$

The corresponding powers for an 18″ slotter were 2·3 and 10·3 H.P., giving an efficiency of 77·5 per cent.

Plate XIII.

The frame is a single casting of $\frac{3}{4}''$ metal, designed to carry all the moving parts of the machine. Its base is large, so that freedom from unsteadiness is ensured without the use of holding-down bolts.

The horizontal surface, over which the saddle moves, consists of two planed strips, $3\frac{1}{4}$in. × 2ft. $1\frac{1}{2}$in., with their outer edges bevelled to an angle of 50°. To afford sufficient bearing area for the ram the frame is widened at the front, and at the top shaped as shown in Fig. 4, Plate XIV, to admit of the passage of the connecting rod.

On the right-hand side are two bosses to support the driving shaft, the one near the front being joined to a flat projection which contains the driving plate, and supports the slotted arm. Bosses are also cast on the frame side to support the feed lever **F** and the horizontal feed shaft **F S**.

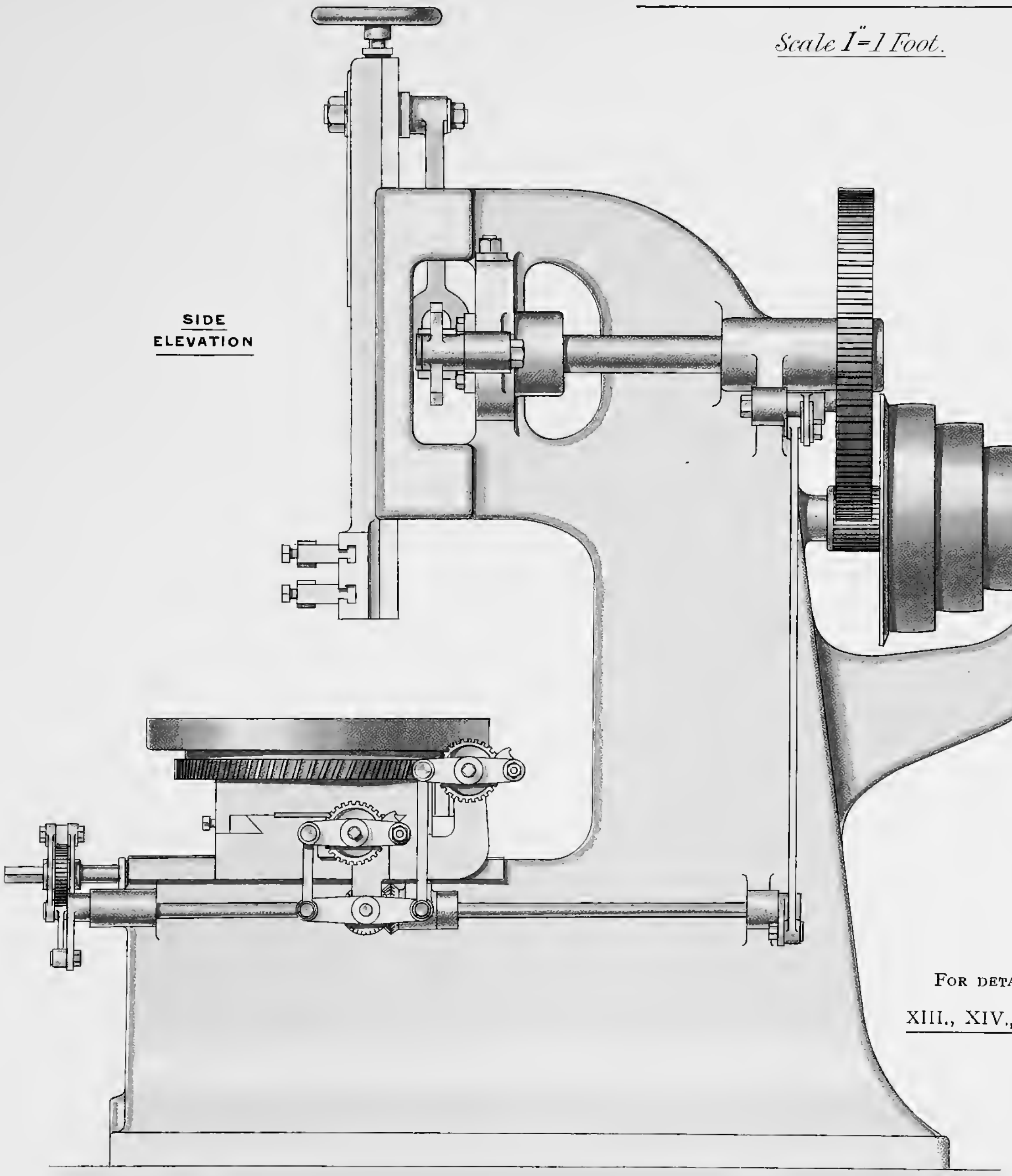
The pulley bracket is made hollow, and cored out through a hole in its under side.

For additional dimensions of the vertical face and pulley bracket see Plates XIV. and XV. respectively.

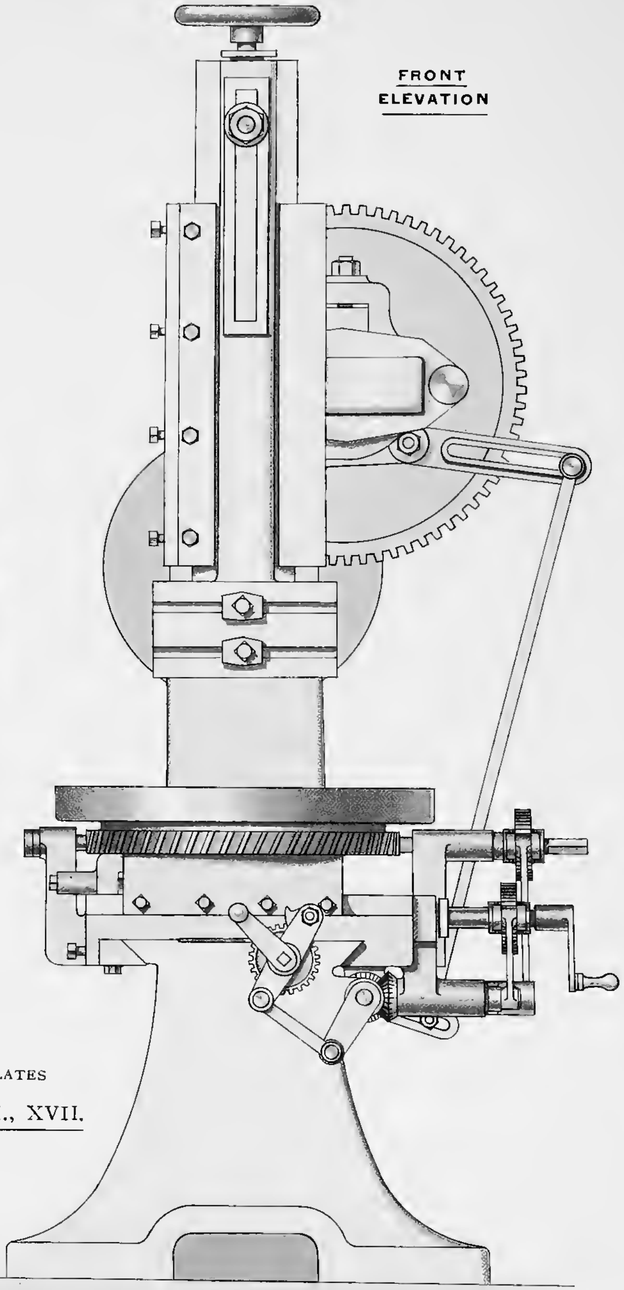
When drawing the frame it should first be set out in straight lines, as indicated on this plate, in order that the inclinations of its various parts may be obtained. It will be seen that some of the curves are made up of two circular arcs of different radii.

9″ STROKE SLOTTING MACHINE.

Scale 1″=1 Foot.



SIDE ELEVATION



FRONT ELEVATION

For details see Plates
XIII., XIV., XV., XVI., XVII.

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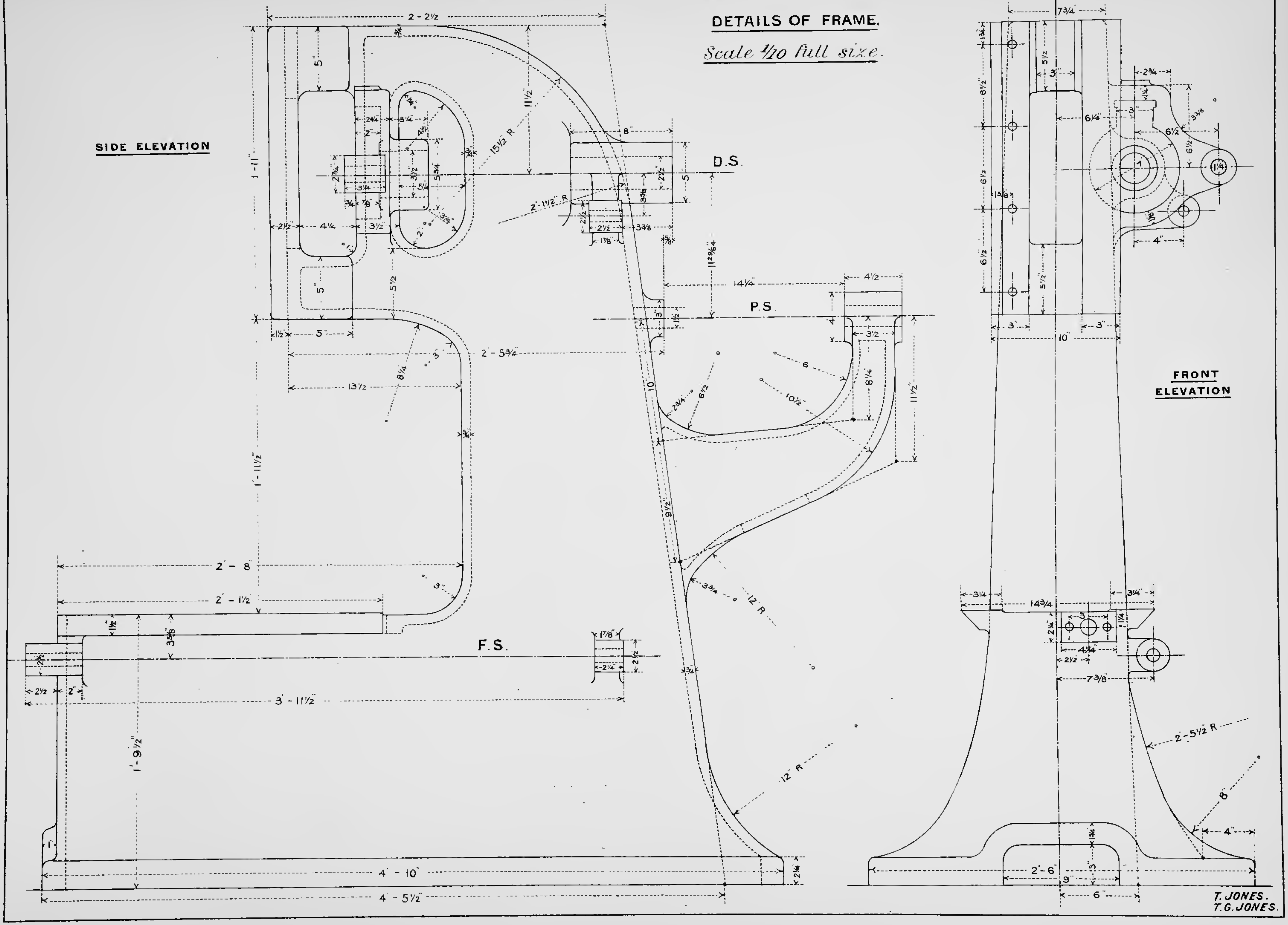
9" STROKE SLOTTING MACHINE.

DETAILS OF FRAME.

Scale 1/10 full size.



T. JONES.
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Plate XIV.—SLOTTING MACHINE.

THE several views, Figs 1 to 5, show the details of the slotting ram **N** and the means by which it is moved up and down, so that the return stroke may be performed in less time than the cutting stroke.

On one end of the driving shaft **D S** is fixed a cast-iron disc **D P**, which turns in a recess in the side projection near the front of the frame (See Fig. 3). The driving pin **P** is fixed on the face of this disc by two bolts fitting in **T** slots to admit of its adjustment from the centre of the shaft to give the required stroke of tool. To take up the wear of the driving plate the pad **B** is pressed against its edge by means of a screw.

The driving pin carries a rectangular cast-iron block which, sliding in the slot of the arm **S A**, gives it a vibratory motion. When the pin is in its extreme outward position, *i.e.*, $2\frac{1}{4}''$ from the centre of the shaft, the vertical motion of the free end of the arm is $9''$—the maximum stroke of the tool. This motion is transmitted to the ram through the cast-iron connecting rod **K**, whose upper end is attached to a prolongation of the nut for the vertical adjusting screw $\mathbf{S_1}$.

The form of the top of the frame, to admit of the motion of the connecting rod, may be clearly seen from the side elevation and plan.

The ram is a long hollow casting with a planed face, which slides against the vertical face of the frame, and is held in position by an adjustable bevelled strip. Its upper part is slotted to receive screw $\mathbf{S_1}$ and admit of the motion of the nut when the ram is being adjusted for height.

The two wrought-iron tool holders **H** are held in horizontal slots formed in the enlarged end.

RATIO OF TIMES OF CUTTING AND RETURNING. (See accompanying diagram.)

Let o be the centre of the driving plate, p the driving pin, and a the centre of oscillation of the arm. When p describes the circle of radius op the arm ab vibrates through the angle $b_1 a b_2$—the vertical distance between b_1 and b_2 being the stroke of the tool. In the diagram $p_1\, p_2$ represents $9''$.

When p is at t_1, the point of contact of $a\, b_1$ with the circle, the tool is in its highest position, and with the given direction of rotation the shaft turns through the angle $t_1\, o\, t_2$ $(=2\alpha)$ before the down stroke ends. For the angle of rotation $t_2\, o\, t_1$ $(=2\beta)$ the arm moves from its lowest to its highest position. So, the angles described by the shaft and driving plate during the cutting and return strokes are 2α and 2β respectively, and assuming that the shaft rotates uniformly, the times of cutting and returning are proportional to α and β respectively.

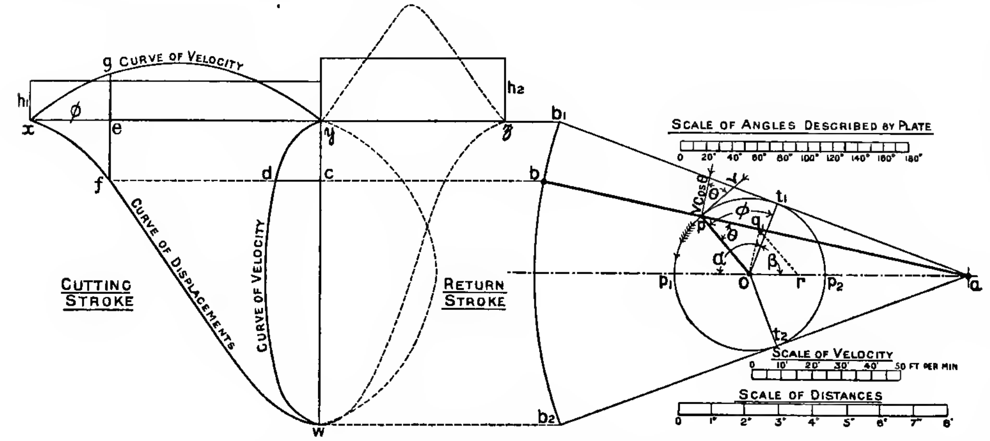
$$\text{or,}\quad \frac{\text{Time of cutting}}{\text{Time of return}} = \frac{\alpha}{\beta}$$

The value of this ratio for any stroke from $9''$ to $3''$ is given in the accompanying table.

$$\text{Cos}\ \beta = \frac{\text{Throw of pin}}{oa} = \frac{\frac{1}{2}\ \text{stroke}}{ab}$$

The value of β is then obtained from trigonometrical tables. Again $\alpha = 180^\circ - \beta$.

Stroke in inches.	Angle β.	Angle α. $[=180^\circ-\beta]$	$\frac{\alpha}{\beta}$	Revs. per min. of driving plate.	Max. vel. of tool in feet per min.
9	69·75°	110·25°	1·58	10·7	18·7
8	72·05°	107·95°	1·50	10·7	17·2
7	74·33°	105·66°	1·42	10·7	15·45
6	76·66°	103·33°	1·35	10·7	13·65
5	78·9°	101·1°	1·28	17·14	18·85
4	81·13°	98·87°	1·22	17·14	15·33
3	83·37°	96·63°	1·16	27·43	19·3



VARIABLE VELOCITY OF TOOL.—The velocity of the tool is continually changing; for the positions t_1, t_2 of the pin its velocity is zero, and is a maximum in the cutting and return strokes when at p_1, p_2 respectively.

The *maximum velocity* during the *cutting stroke* may be determined as follows:—

Let n = revolutions of driving plate per minute, r = radius op in feet, then velocity v of pin in feet per minute $= 2\pi r\, n$.

The point on the arm in contact with the pin at p_1 has a velocity v, $\therefore$ velocity of end $b = \dfrac{v \times ab}{ap_1}$ feet per minute.

From the notes to Plate XV. it will be seen that the three possible speeds of the shaft are 10·7, 17·14 and 27·43 revolutions per minute.

Assuming the shaft makes 10·7 revolutions per minute, then the maximum cutting speed of tool, when the stroke is $9''$ is calculated to be 18·7 feet per minute: where $r = 2\frac{1}{4}''$, $ap_1 = 8\frac{3}{4}''$ and $ab = 13''$.

For the same maximum speed of cutting, the rate of rotation must increase as the stroke diminishes.

[*Continued.*

9" STROKE SLOTTING MACHINE.

DETAILS OF RAM, OSCILLATING ARM, &c.

Scale 1¾" = 1 Foot.

SIDE ELEVATION

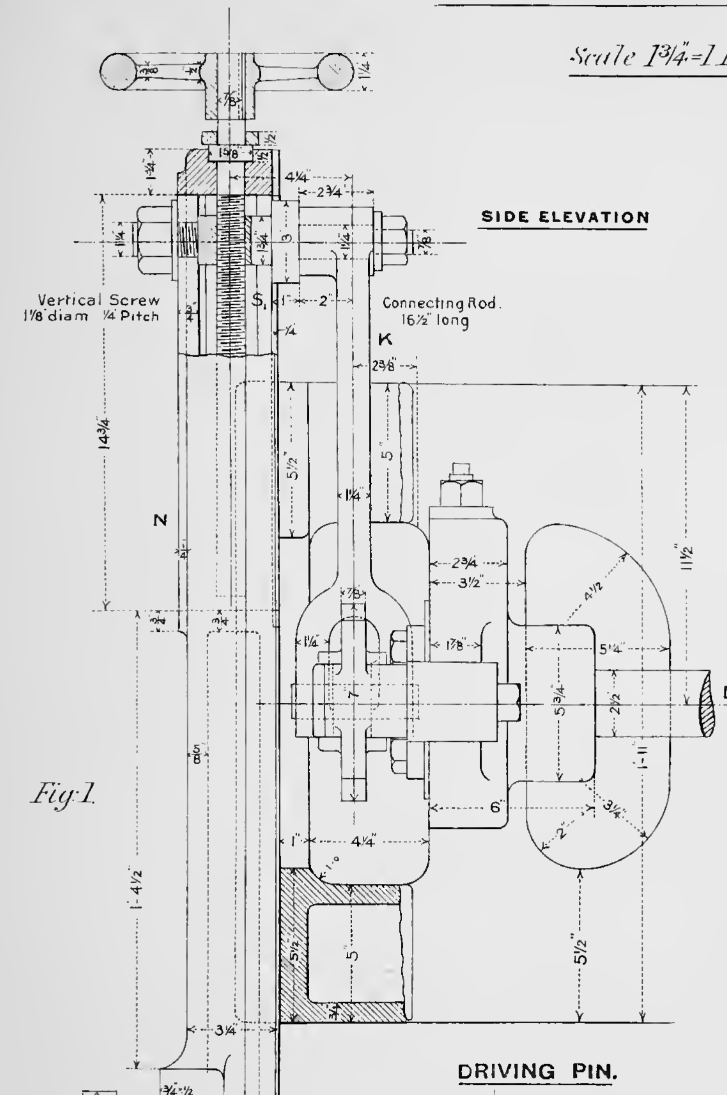


Fig. 1.

FRONT ELEVATION

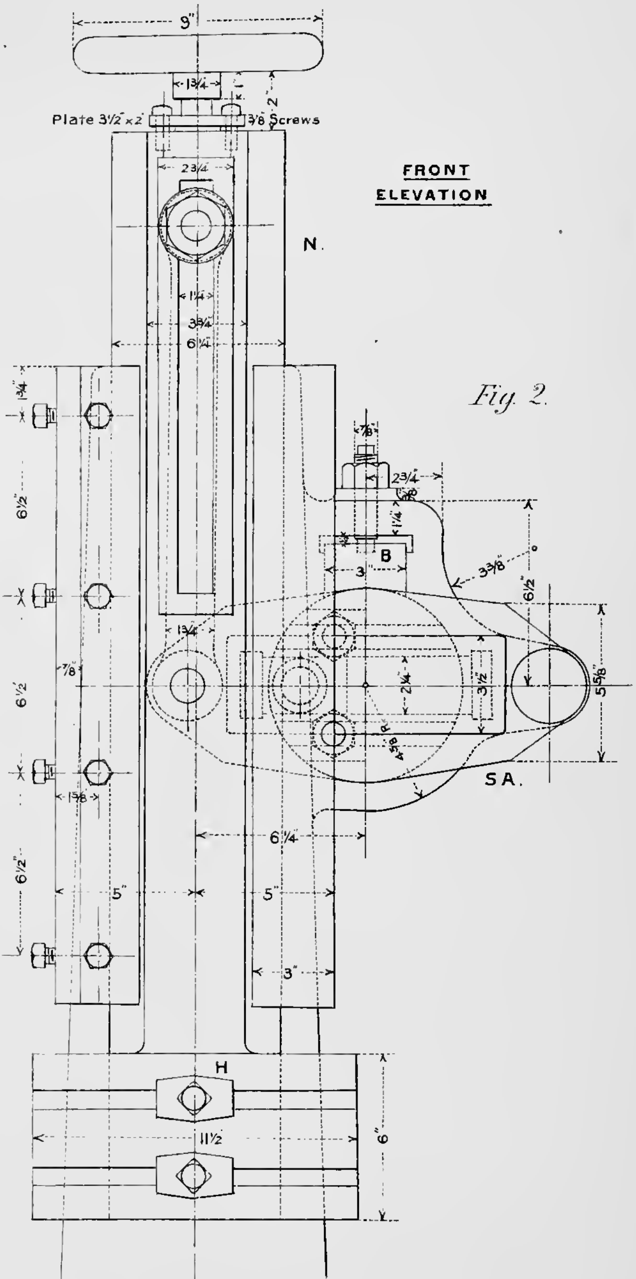


Fig. 2.

DRIVING PIN.

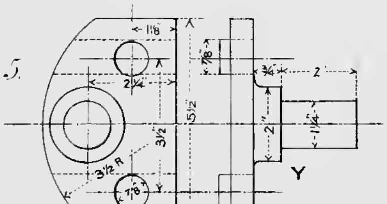


Fig. 5.

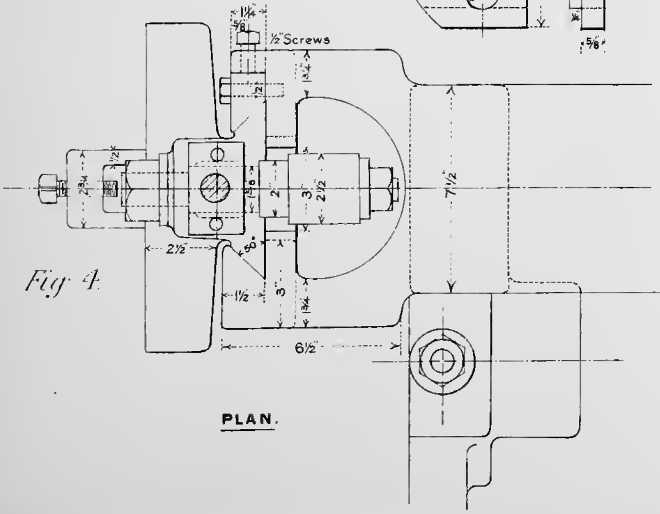


Fig. 4.

PLAN.

SECTIONAL PLAN

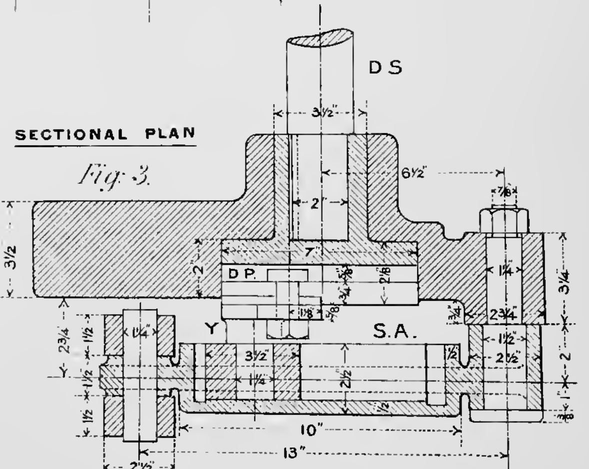


Fig. 3.

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PLATE XIV.—*Continued.*

TO DETERMINE THE ANGULAR VELOCITY OF THE ARM FOR ANY POSITION OF THE DRIVING PIN

Let θ = angle between radius *op* and arm *ab*.

ω_a, ω_c = angular velocities of arm and radius *op* respectively.

v = linear velocity of pin *p*.

$$\omega_c = \frac{v}{op}, \quad \omega_a = \frac{v \cos\theta}{ap} \quad \therefore \frac{\omega_a}{\omega_c} = \frac{\frac{v\cos\theta}{ap}}{\frac{v}{op}} = \frac{op \cos\theta}{ap}$$

If *oq* is at right angles to *ab* and *qr* parallel to *op*, then $op \cos\theta = qp \;\therefore\; \frac{\omega_a}{\omega_c} = \frac{qp}{ap} = \frac{or}{oa}$

Hence, *o a* of constant length represents the constant angular velocity of the driving plate, and *o r*, the instantaneous angular velocity of the arm.

To a different scale *o r* represents the linear velocity of the end *b* of the arm and of the tool.

The maximum angular velocity during the cutting stroke is not determined by this construction, but geometrically as a fourth proportional. $a p_1 : a o :: o p : \omega_a$.

Diagrams of displacement and velocity.

Through the point b_1 draw the line *x y z* parallel to the centre line *a o*, and make *x y* and *y z* to represent the angles 2α and 2β respectively. They may conveniently be made equal to the arcs $t_1 p_1 t_2$ and $t_2 p_2 t_1$ respectively, the arcs which those angles subtend.

Through the points *e*, *b*, where *x e* represents the angle ϕ, draw lines respectively perpendicular and parallel to the line of centres, and make $c d = e g = o r$ to represent the linear velocity of *b*. Then, *e f* represents the displacement of the tool from its highest position, and *e g* its velocity when the driving plate has described the angle ϕ after the beginning of the stroke: also, for the displacement $y c \left[= e f\right]$ the velocity of the tool is represented by *c d*.

The loci of the points *f*, *g*, *d* are the displacement curve and the velocity curves on time and distance bases respectively.

The corresponding curves for the return stroke are drawn in a similar manner.

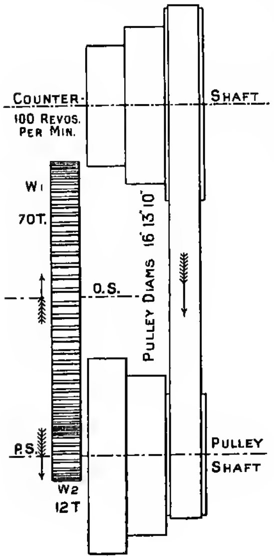
The scale of velocity can be drawn when the maximum velocity is calculated and the line which represents it determined graphically as suggested above.

The ratio of the mean heights h_2, h_1 of the velocity diagrams on time bases is equal to the ratio of the angles described by the plate during the cutting and return strokes.

Plate XV.—SLOTTING MACHINE.

THE pulley shaft **P S** is carried at its ends by the frame and the bracket, and is prevented from turning by a screw passing half through the boss of the bracket and half through the shaft. Turning freely on it is the cone pulley **C**, to the front plate of which the pinion $\mathbf{W}_2$ is keyed. Oil is passed to the shaft through the two small brass tubes. The pulley receives its motion from an equal pulley keyed on the counter-shaft running at 100 revolutions per minute.

Above the pinion, and gearing with it, is the spur wheel $\mathbf{W}_1$, keyed to the driving shaft **D S**. On the inner face of the wheel is a groove **G**, so shaped that during a small fraction of a revolution the pin fitting in it receives a vertical motion of $\frac{5}{8}''$ down and up, and then remains in its highest position until the completion of the revolution.



By a combination of levers and links this motion effects the feed of the machine table in any horizontal direction. In order that the feed may take place before the beginning of a new cut, the driving plate must be keyed to the shaft in such a position that the pin receives its motion in the interval between the tool leaving and again reaching the work.

The first feed lever **F** is centred to a projection on the side of the frame, and in consequence of its connection with the arm $\mathbf{A}_1$ by the rod **R**, whose ends may be fixed in any positions in the slots, the angular motion of the feed shaft **F S** may be varied from 5° to 30°.

(1)—*Pulley Shaft.* SPEED OF PULLEY AND DRIVING SHAFT.

Maximum speed $= 100 \times \frac{16}{10} = 160$ revolutions per minute.

Intermediate „ $= 100$ „ „

Minimum „ $= \frac{100 \times 10}{16} = 62{\cdot}5$ „ „

(2)—*Driving Shaft.*

The speed is reduced in the ratio of 12 to 70 by the wheel gearing.

Maximum speed $= \frac{160 \times 12}{70} = 27{\cdot}4$ revolutions per minute.

Intermediate „ $= \frac{100 \times 12}{70} = 17{\cdot}14$ „ „

Minimum „ $= \frac{62{\cdot}5 \times 12}{70} = 10{\cdot}7$ „ „

The table facing Plate XIV. shows what speed is suitable for any particular stroke.

9" STROKE SLOTTING MACHINE.

DETAILS OF DRIVING PULLEY, WHEELS AND LEVERS FOR FEED MOTION.

Scale 1¾" = 1 Foot.

Wheel – 70 teeth (Involute)
1" Pitch
Depth of Tooth ⅔ Pitch
Diameter 22·28".
Pinion – 12 Teeth.
Diameter 3·82".

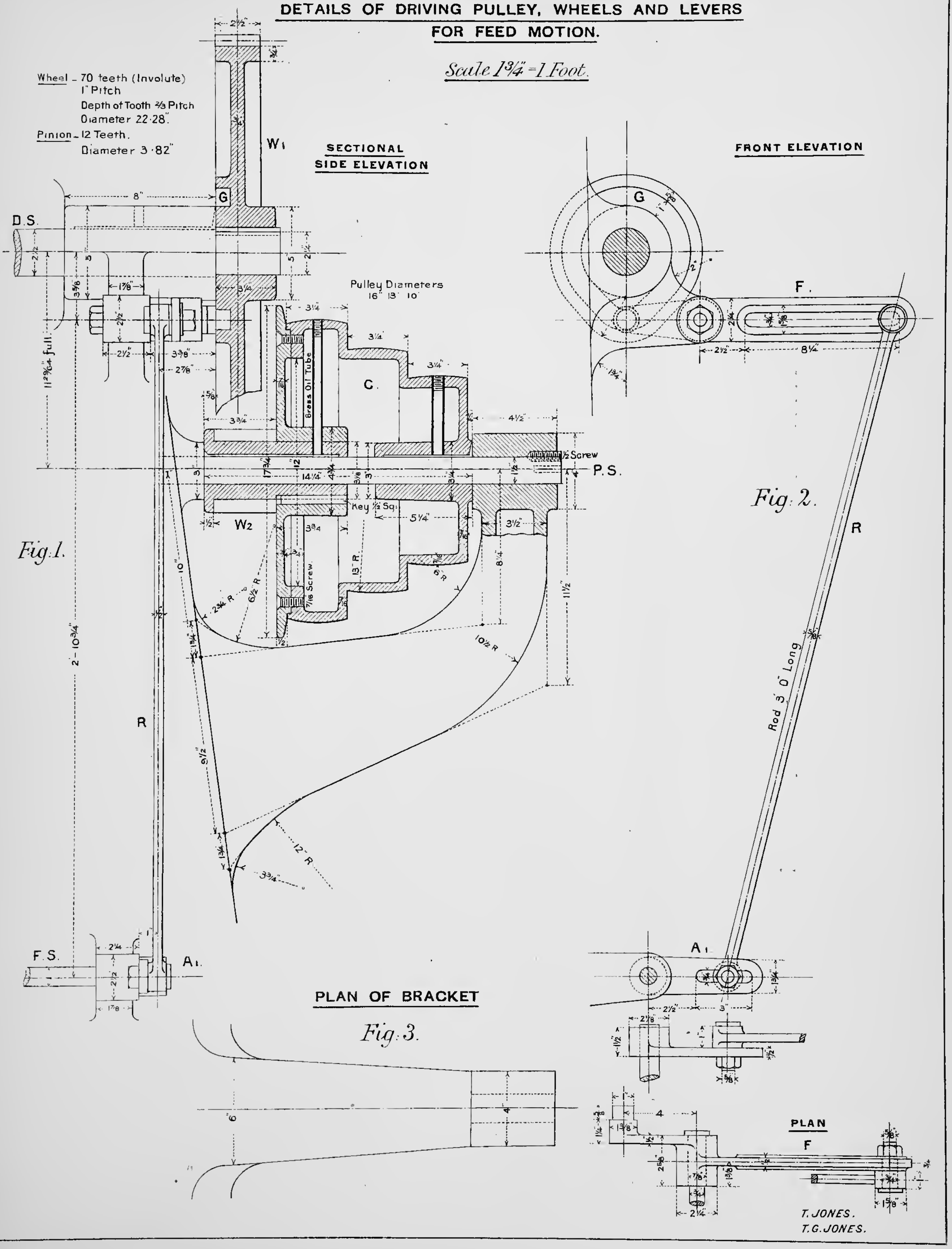


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Plate XVI.—SLOTTING MACHINE.

THE table and slides are so arranged that the former, and the work fixed to it, may receive motion in either of two horizontal directions at right angles, or a circular motion.

THE SADDLE D moves over the horizontal planed face of the frame, actuated by the left-hand screw **S_2** which is supported at its outer end by the frame. The feed, when effected automatically, may be varied from $\frac{1}{45}$th to $\frac{1}{270}$th of an inch per cutting stroke. An ordinary bevelled adjustable strip is used to follow up the wear of the sliding surfaces.

Cast with the saddle are two arms to support the worm shaft **WS**, and two bosses to carry the feed mitre wheel **M_1**, and the shaft of the wheel **M_2** and cast-iron lever **K**. The worm shaft is held endways by a shoulder near one end and lock nuts on the other.

THE SLIDE E is moved across the saddle by the screw **S_3**, and carries the circular table **T**.

The worm bracket, supporting the shaft immediately on each side of the wrought-iron worm, is fixed to the side of the slide by two $\frac{5}{8}''$ screws. In order that the worm may receive the angular motion of the shaft for all positions of the slide, it is fitted with a feather key which slides along a key groove in the shaft.

To admit of circular motion the table is formed with a conical base which fits in a corresponding semi-circular recess in the slide, and is held in position by the lock strip **LS**. The $\frac{3}{4}''$ screw is used for locking the table when no circular motion is required, and the $\frac{3}{4}''$ stud is permanently adjusted to give a correct working fit to the table when the locking screw is released.

The two parallel edges of the strip are bevelled to an angle of 50°, and at the bottom are $10\frac{1}{2}''$ apart so that the table base, 10″ diameter, may easily be passed into its position.

The maximum automatic feeds of the slide and table are $\frac{1}{45}''$ and $\frac{1}{3}°$ respectively per cutting stroke. (See notes to Plate XVII. for the method of determining the amount of feed.)

The nuts for the two screws **S_2**, **S_3** are of brass, and are held in position by circular projections upon them fitting into holes in the saddle and slide respectively.

9" STROKE SLOTTING MACHINE.

DETAILS OF TABLE AND SLIDES.

Scale 2"=1 Foot.

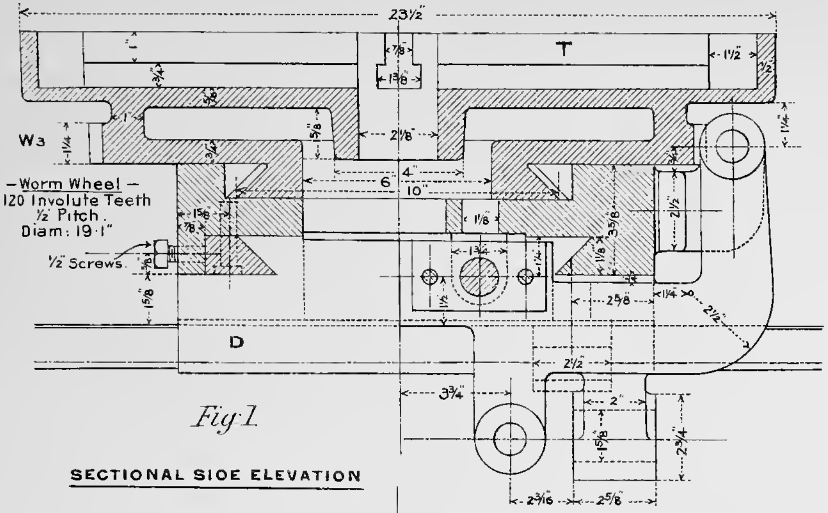


Fig. 1.

SECTIONAL SIDE ELEVATION

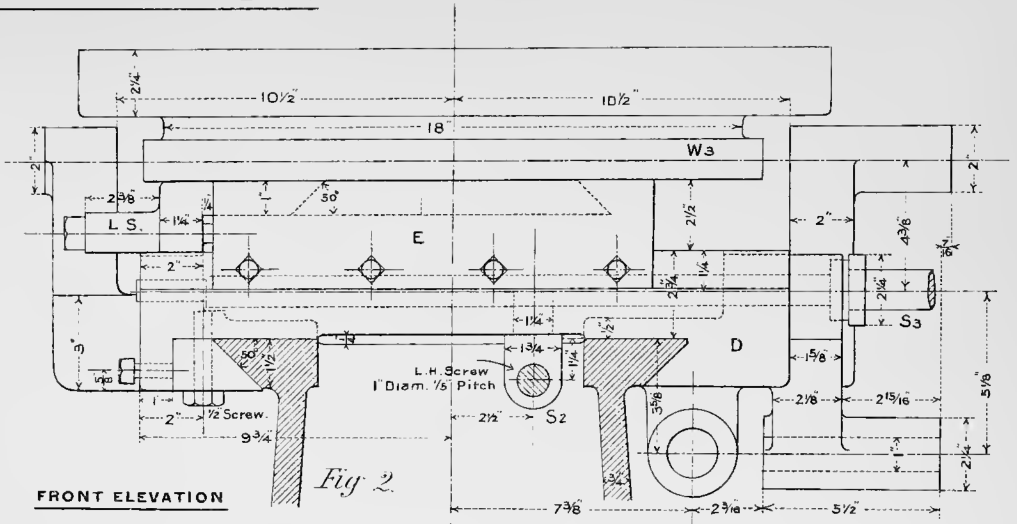
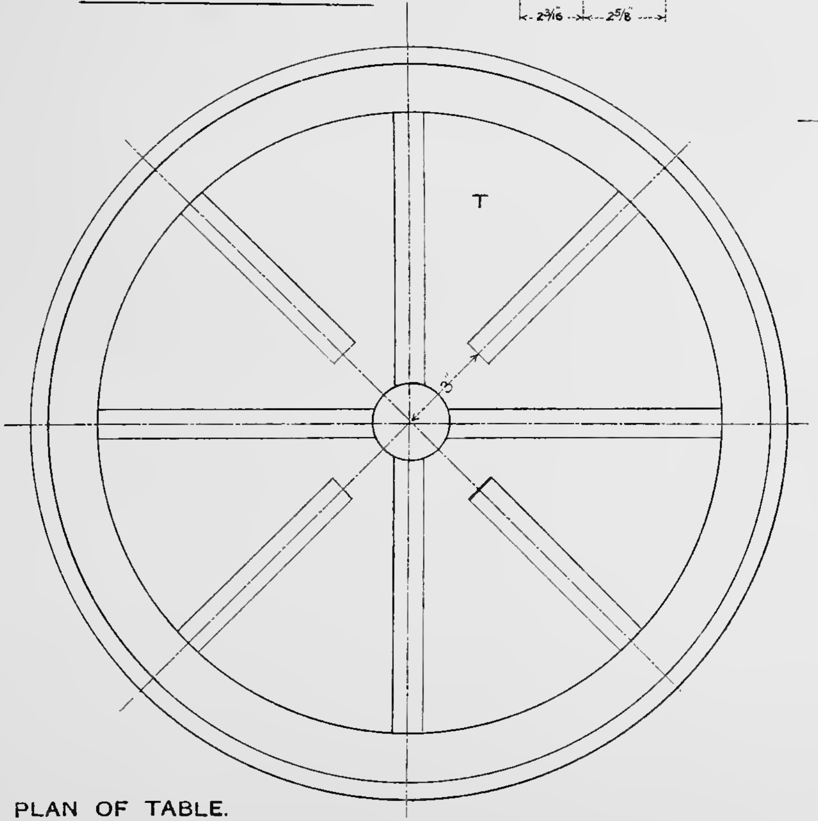


Fig. 2.

FRONT ELEVATION



PLAN OF TABLE.

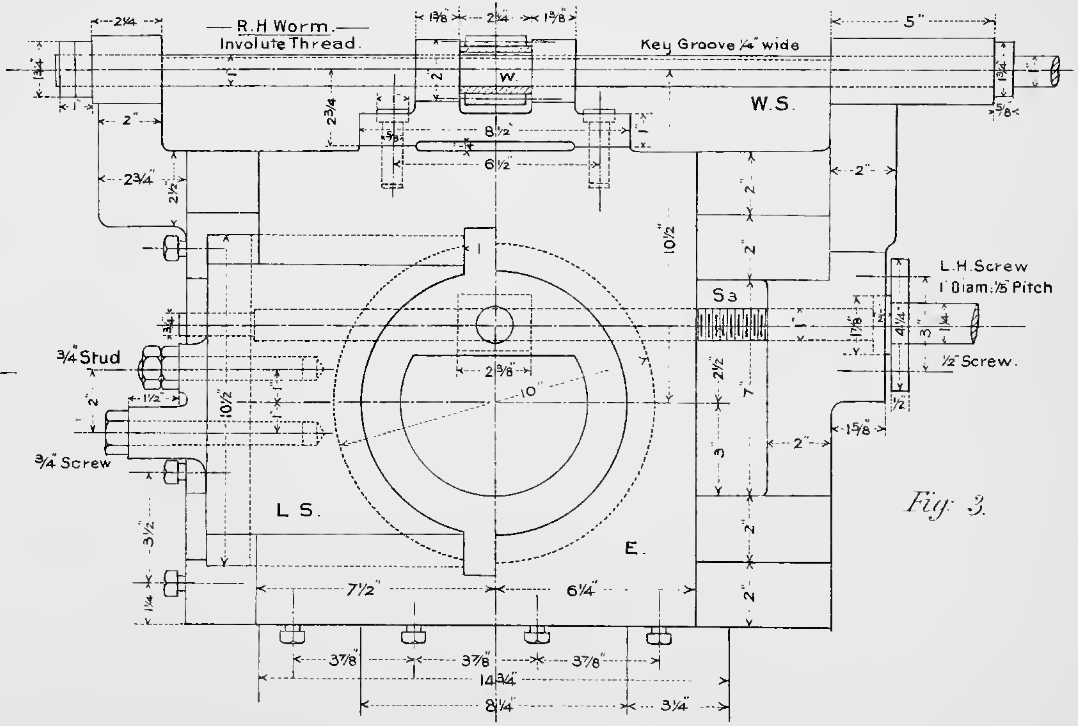


Fig. 3.

PLAN WITH TABLE REMOVED.

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Plate XVII.—SLOTTING MACHINE.

FEED MOTION.—Figs. 1 to 7 show the arrangement of levers &c., by means of which the intermittent motion of the feed lever **F** is transmitted to the screws $\mathbf{S_2}$, $\mathbf{S_3}$ and the worm shaft **W S**. The horizontal feed shaft **F S** is supported at its ends by simple bearings cast on the side of the frame, and immediately outside these are fixed the arms $\mathbf{A_1}$, $\mathbf{A_2}$: the former is connected with the feed lever **F** by the rod **R**, and the latter is used to transmit the motion of the shaft to the pawl lever $\mathbf{V_1}$ which is free to turn on the end of the screw.

To connect the screw $\mathbf{S_3}$ and the worm shaft with **F S**, mitre wheels $\mathbf{M_1}$, $\mathbf{M_2}$ are used. $\mathbf{M_1}$ slides along the shaft, being carried by the bearing formed with the saddle as shown in Fig. 7, and $\mathbf{M_2}$ is keyed to a short shaft which is also supported by the saddle. By means of the links $\mathbf{L_2}$, $\mathbf{L_3}$ the motion of the lever **K** is transmitted to the pawl levers $\mathbf{V_2}$, $\mathbf{V_3}$ respectively.

When the pawl is in gear with the ratchet wheel, during the motion of the lever in one direction, the shaft or screw carrying the wheel is turned and so the feed given.

It will be seen that a pawl lever is formed of two cast-iron pieces separated by a pawl and one end of a link.

In order that the pawl may not tend to change its position when in or out of gear with the wheel, the pin carrying it has three flat faces as shown in Fig. 6, against one of which presses the small plunger contained within the pawl.

This simple device enables it to be maintained in three positions, viz., in gear on either side of the lever and out of gear.

For the rapid adjustment and hand feed of the table the ends of the screws and the shaft project beyond the pawl levers, and are of square section to receive the handles.

DETERMINATION OF FEED.—Assuming the given positions of the levers to correspond with the highest position of the feed pin (*i.e.*, before the beginning of the feed) when the rod **R** is adjusted for maximum feed, the angular advance of each of the pawl levers $\mathbf{V_1}$, $\mathbf{V_2}$, $\mathbf{V_3}$, at the end of the return stroke, is about 40°—this being produced by a motion of 30° of the arm $\mathbf{A_2}$.

The smallest possible motion of $\mathbf{A_2}$ is 5°, and it will be sufficiently accurate to say that the minimum motion of a pawl lever is $\frac{1}{6}$th of the maximum.

Maximum feed of saddle or slide $= \frac{40}{360} \times$ pitch of screw $= \frac{40}{360} \times \frac{1}{5} = \frac{1}{45}''$.

Minimum feed $= \frac{1}{6} \times \frac{1}{45} = \frac{1}{270}''$.

For one revolution of the worm the wheel turns through $\frac{1}{120}$th of a revolution, since it has 120 teeth, and therefore for a motion of 40° of the former the latter moves through $\frac{40}{360} \times \frac{1}{120} \times \frac{360}{1} = \frac{1^\circ}{3}$.

9" STROKE SLOTTING MACHINE.

DETAILS OF FEED MOTION.

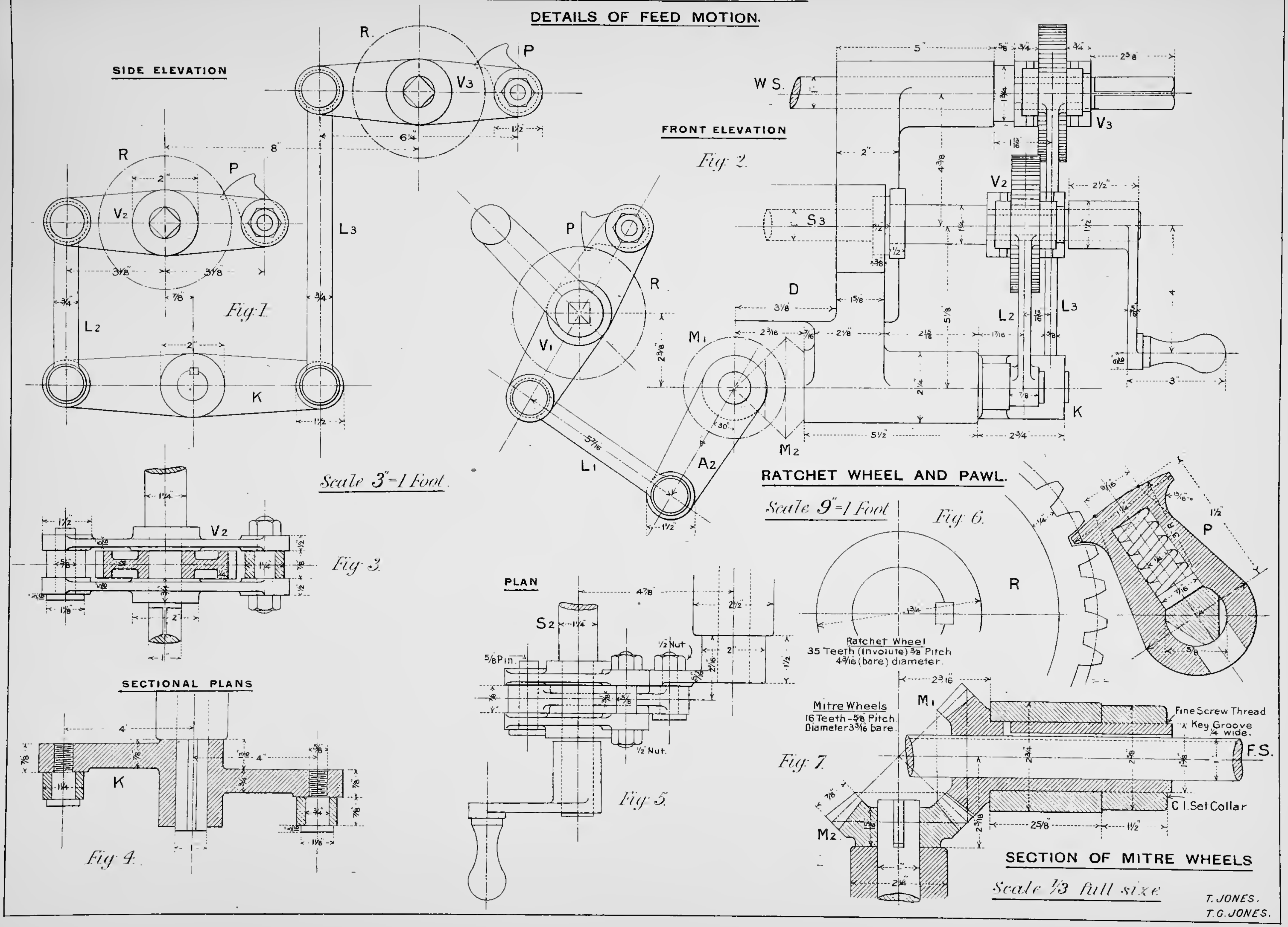

Fig: 1.

Fig: 2.

Scale 3"=1 Foot.

Fig: 3.

SECTIONAL PLANS

Fig: 4.

PLAN

Fig: 5.

RATCHET WHEEL AND PAWL.

Scale 9"=1 Foot.

Fig: 6.

Ratchet Wheel
35 Teeth (Involute) 3/8 Pitch
4 3/16 (bare) diameter.

Mitre Wheels
16 Teeth - 5/8 Pitch
Diameter 3 3/16 bare.

Fig: 7.

SECTION OF MITRE WHEELS

Scale 1/3 full size

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Plate XVIII.—SHAPING MACHINE.

GENERAL DESCRIPTION.—The shaping machine, of which detailed drawings are given on Plates XIX. to XXIII., is made by Messrs. John Hetherington and Sons Ltd., Manchester. It is capable of producing horizontal, inclined or cylindrical surfaces not exceeding 10″ in length.

The counter-shaft from which the machine receives its motion is $1\frac{3}{4}''$ diameter, 3′–3″ between the bearings, and carries fast and loose pulleys 14″ diameter, $3\frac{1}{2}''$ wide, and a cone pulley of the same size as that on the driving shaft of the machine.

The bed **B**, supported on two standards, carries all the fittings of the machine. At the back the pulley shaft **DS** is supported by two arms **E**, **E** and connected by a pinion, sliding with the carriage, to the wheel W_2 which carries the sliding block for actuating the slotted arm **S A**.

The wrought-iron rod **K** connects the arm with the ram **R**, to which it gives a reciprocating motion across the carriage of continually varying velocity with a quick return. The ratio of the times of cutting and returning decreases with the stroke, its value being 2 to 1 when the stroke is 10″.

With the counter-shaft making 120 revolutions per minute the number of cutting strokes may be 56·2, 34·3 or 20·7 per minute. For constant maximum and mean cutting speeds the revolutions of the driving pulley must be increased as the stroke decreases. .

The tool box **T B** is carried on the front end of the ram and constructed so that the tool can be fed in any direction in a vertical plane. When the back slide is vertical the feed may be effected automatically at the end of the return stroke.

The feed screw S_1 of the carriage carries on one end two ratchet wheels G_1, G_2, the former keyed and the latter turning freely on it and in gear with an equal wheel G_3 keyed on the worm shaft S_2.

The pawl lever is connected by the link L_1 to the feed lever whose end fits in an eccentric groove on the wheel W_4 in gear with W_3 on the pulley shaft. With a pawl gearing with G_1 the carriage is fed across the bed by an amount which may be varied from 18·4 to 110 strokes per inch of feed according to the position of the link L_1.

Pieces with cylindrical surfaces to be tooled are held on the circular motion mandril by conical bushes, and turned slightly with it at the end of each return stroke; the mandril carries a worm wheel in gear with a worm on the shaft S_2.

For the circular feed the pawl above G_2 is turned over, and so the forward intermittent motion of the lever is transmitted to G_3 on the end of the shaft.

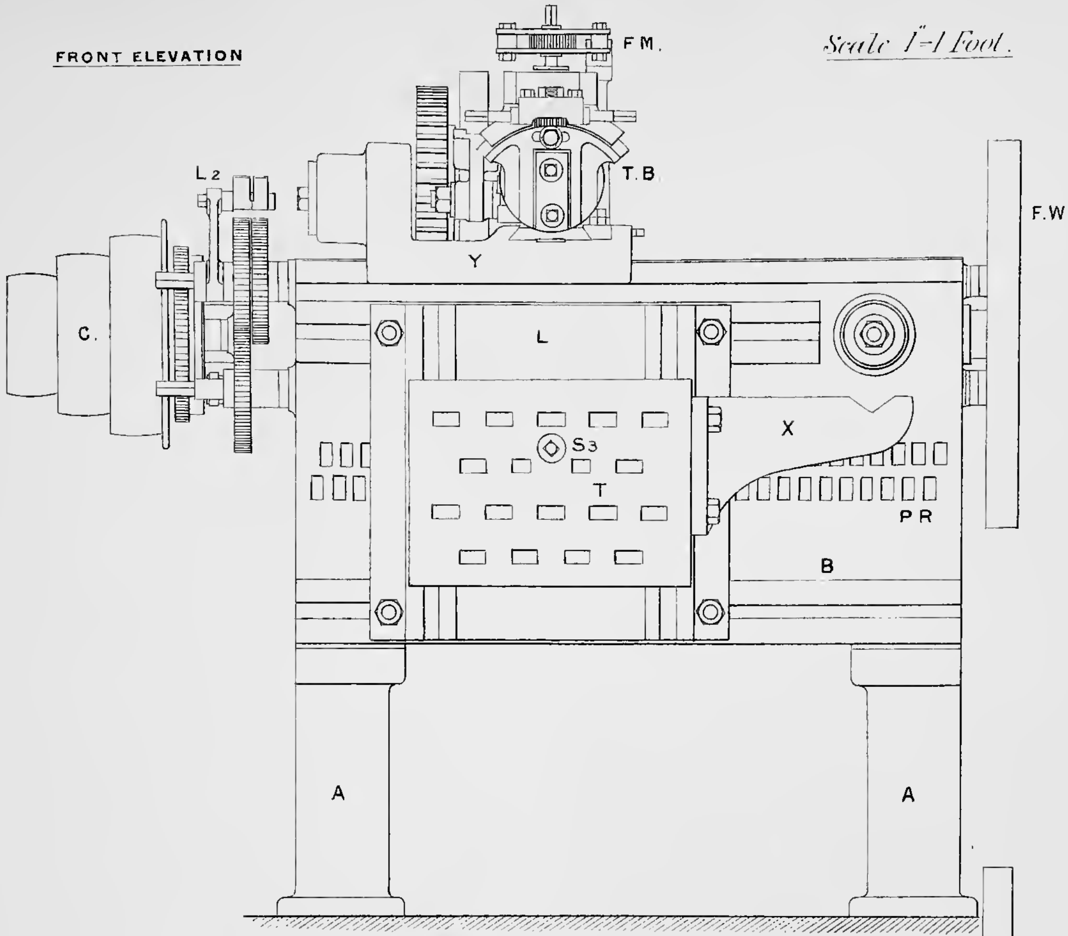
The connections of the table **T** to the slide **L** and the latter to the bed are such that the table can be moved both vertically and horizontally. The former adjustment is effected by turning the horizontal screw S_3, and the latter by means of a bar used in the pinching rack **P R**.

The stay **X**, bolted to the side of the table, is placed under the outer conical bush on the mandril to steady the work during cutting.

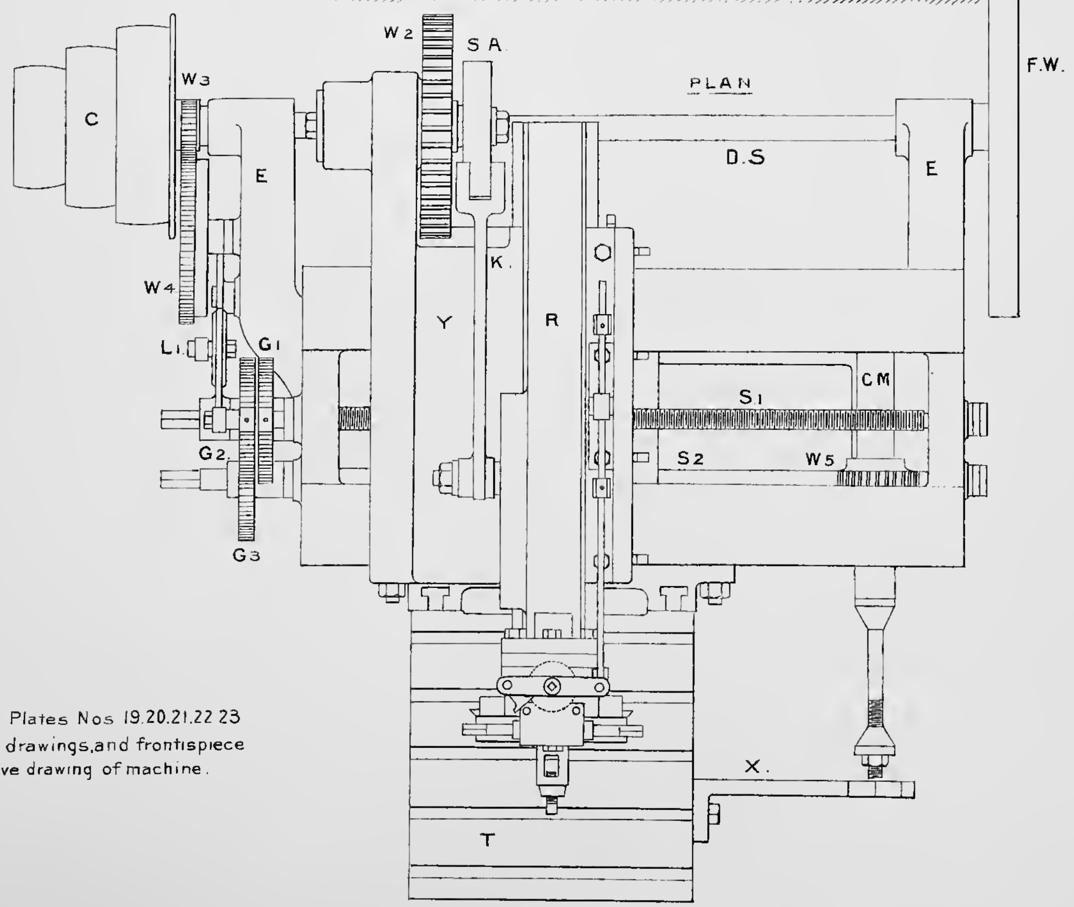
10" STROKE SHAPING MACHINE.

Scale 1" = 1 Foot.

FRONT ELEVATION



PLAN



NOTE: See Plates Nos 19.20.21.22 23
for detailed drawings, and frontispiece
for perspective drawing of machine.

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Plate XIX.—SHAPING MACHINE.

DETAILS OF BED.—The machine bed is of box form, 3′ long × 2′ high × 1′ 3″ wide, and has cast with it two horizontal arms **E, E** to support the driving shaft **D S.** They are of ⊓ section, and the one at the pulley end of the shaft carries the feed wheel and lever.

The top face of the bed consists of two parallel strips $5\frac{1}{4}''$ wide, with their outer edges bevelled to an angle of 50°. At each end the bed is secured to a stand **A** (Fig. 4) by two $\frac{7}{8}''$ bolts. It will be noticed that the centre line of the stand does not coincide with that of the bed, and that the bolt holes on the top of the stand are not symmetrically placed.

Across the bed is a central web $\frac{7}{8}''$ thick with top and bottom flanges 3″ wide, the former one shaped to admit of the passage of the brass nut for the feed screw $\mathbf{S_1}$.

The table slide is supported by four bolts held in two horizontal **T** slots, and moved along the bed by means of a lever whose end is placed successively in the semi-circular holes of the pinching rack **P R.**

Passing from one end to the other are the horizontal feed screw $\mathbf{S_1}$ and the worm shaft $\mathbf{S_2}$. Each turns in supports cast on the bed and is held endways by a shoulder at one end and circular lock nuts at the other. The wrought-iron worm, of which no drawing is given, used to transmit the intermittent motion of the shaft to the circular motion mandril, is keyed tightly on the shaft directly below the wheel.

To support the mandril, bosses are cast on the two sides of the bed, the one on the front being fitted with a conical cast-iron bush not shown in the drawing.

10" STROKE SHAPING MACHINE.

DETAILS OF BED.

FRONT ELEVATION

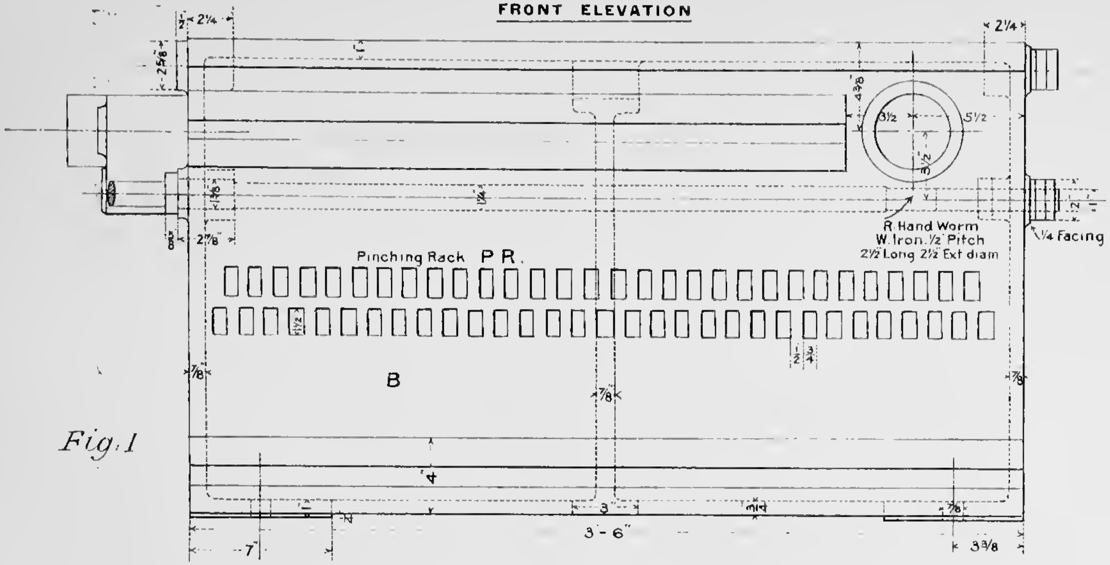

Fig. 1

END ELEVATION

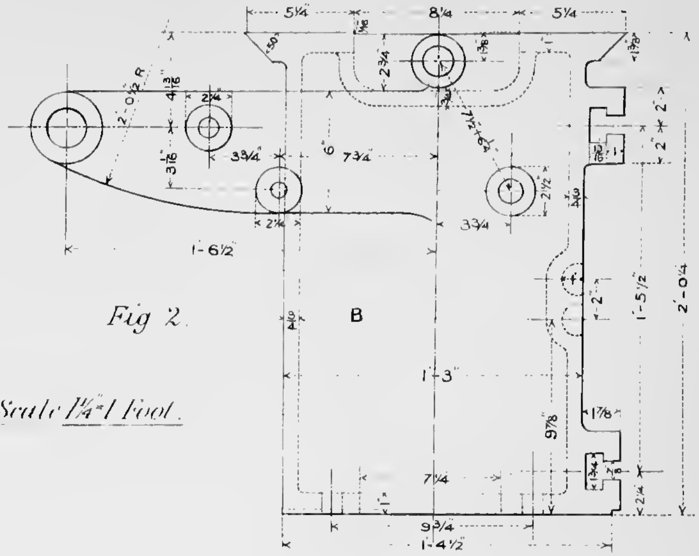

Fig 2.

Scale 1¼"=1 Foot.

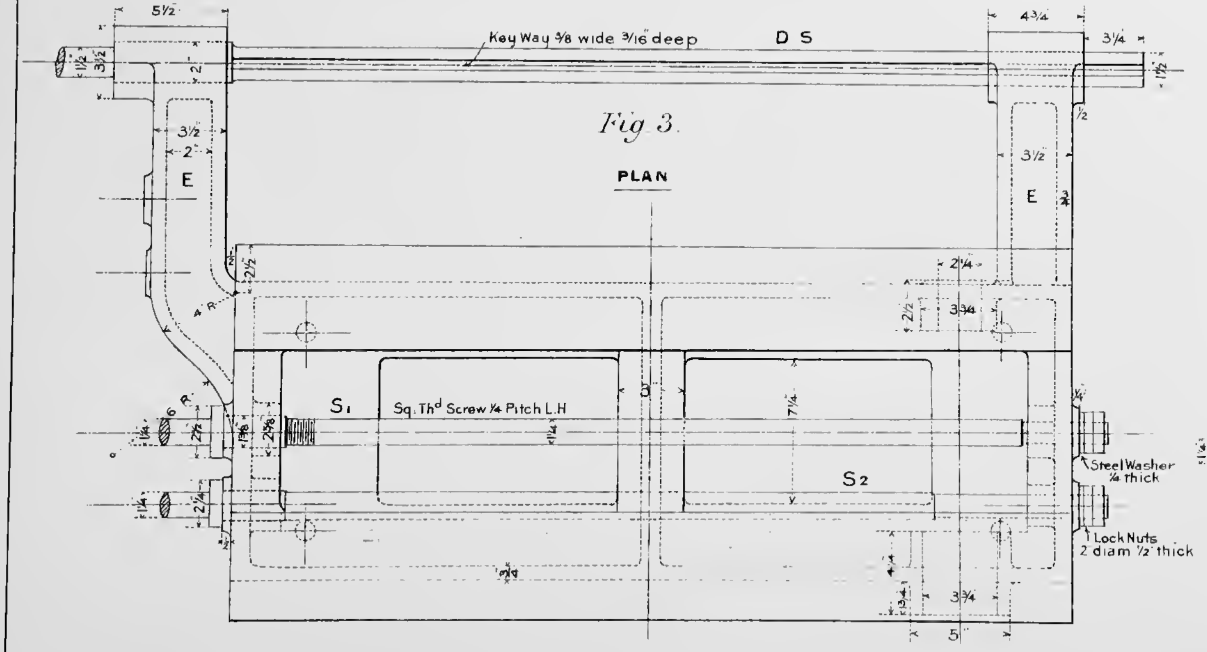

Fig 3.

PLAN

STAND FOR BED.

Scale 1¼"=1 Foot.

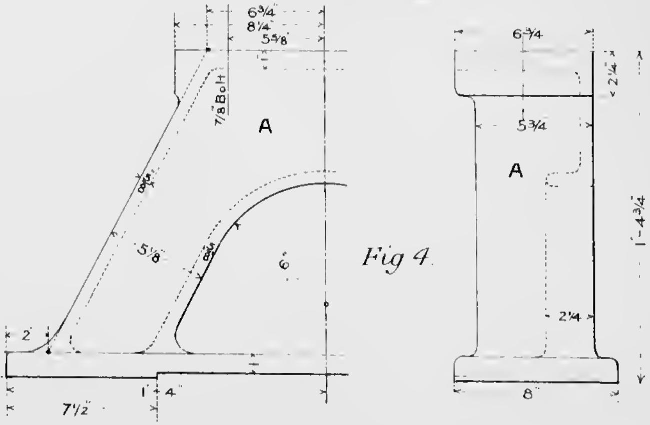

Fig 4.

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Plate XX.—SHAPING MACHINE.

DETAILS OF TABLE AND SLIDE.—The cast-iron table T, carrying the piece to be shaped, is bolted to the slide L by four $\frac{7}{8}$″ bolts held in vertical T slots. The slide L is itself secured to the front of the bed by four bolts. These connections enable the table to be moved both vertically and horizontally. For the vertical adjustment the four nuts on the bolts in the vertical slots are slackened and motion given to the screw S_4 by turning the horizontal shaft S_3, which is connected with it by the mitre wheels M_1, M_2. The brass nut for the screw is fixed to the plate L as shown in the sectional elevation (Fig. 1). The screw is held endways by a $\frac{3}{16}$″ pin passing through the table and fitting in a semicircular groove on the end of the screw. For one revolution of the handle fixed on the square end of the shaft S_3 the table will be moved vertically through $\frac{1}{4}$″—the pitch of the screw.

To relieve the bolts from cross strain there are, on the vertical faces of the table and slide, parallel projections $\frac{7}{8}$″ wide × $\frac{1}{4}$″ thick fitting into the slots.

The table is provided on the top with T slots, and on the sides and front with rectangular bolt holes $1\frac{3}{4}$″ × $\frac{13}{16}$″ to hold $\frac{3}{4}$″ clamping bolts. In the latter particular the table shown on this plate differs from that on the perspective drawing.

Fig. 5 shows a sectional plan of the circular motion mandril. It consists of a cast-iron sleeve and a central steel spindle. The former has a conical end which turns in a cast-iron bush fixed in the front boss on the bed, and is held endways by two wrought-iron circular lock nuts screwed on the small end at the back of the machine. The portion of the spindle beyond the support is turned down to $\frac{3}{4}$″ diameter, screwed, and provided with two cone bushes, one capable of adjustment. The spindle may be turned relative to the sleeve by slackening the nut on its end.

Passing through the piece to be tooled is a drilled hole concentric with the required cylindrical surface, and through this the mandril passes. So long as the hole is not more than $2\frac{1}{2}$″ diameter the piece will be held truly by the bushes when they are pressed tightly against the edges.

To steady the mandril during the cutting, the large end of the outer bush is supported in the V groove of the stay X (Fig. 4), which is bolted to the right-hand side of the table by two $\frac{3}{4}$″ bolts as shown in the general drawing on Plate XVIII.

10" STROKE SHAPING MACHINE.

DETAILS OF TABLE AND SLIDE.

Scale 1¾"=1 Foot.

SECTIONAL ELEVATION AT A B

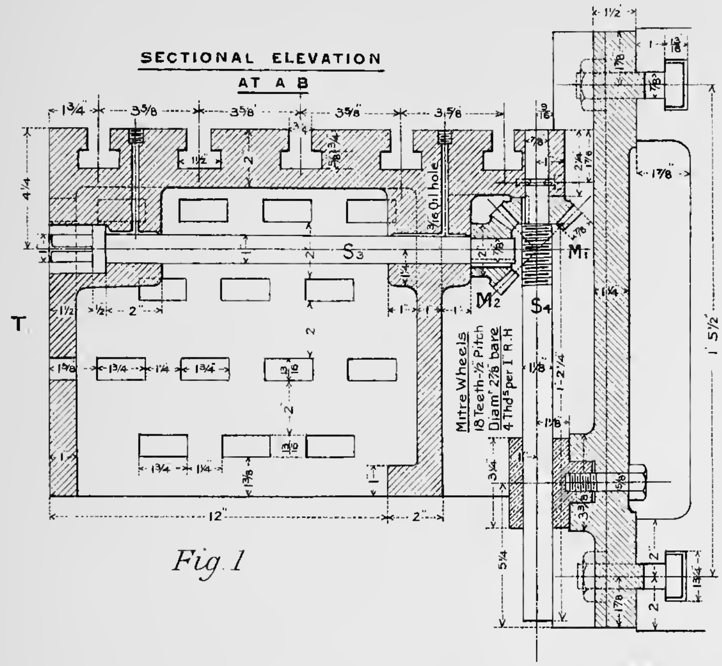

Fig. 1

END ELEVATION OF TABLE

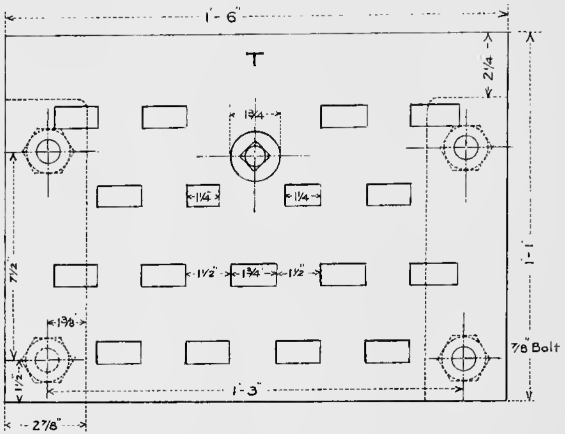

Fig. 2.

PLAN

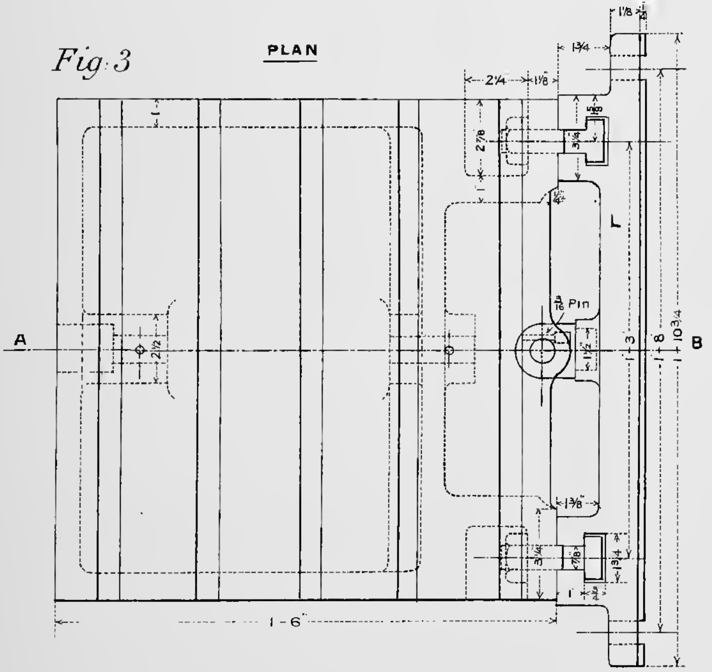

Fig. 3

STAY FOR SUPPORTING CIRCULAR MOTION MANDRIL.

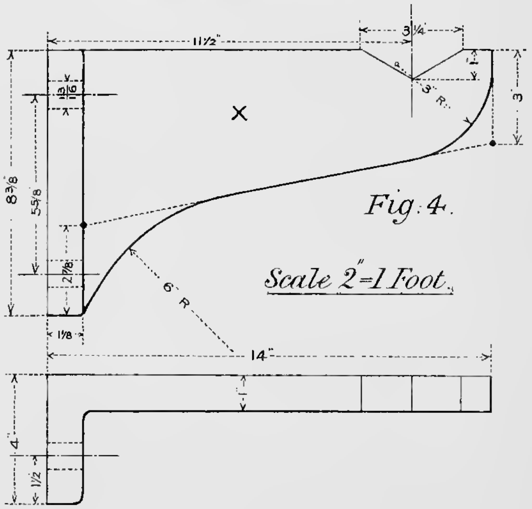

Fig. 4.

Scale 2"=1 Foot.

CIRCULAR MOTION MANDRIL.

SECTIONAL PLAN

Scale 3"=1 Foot.

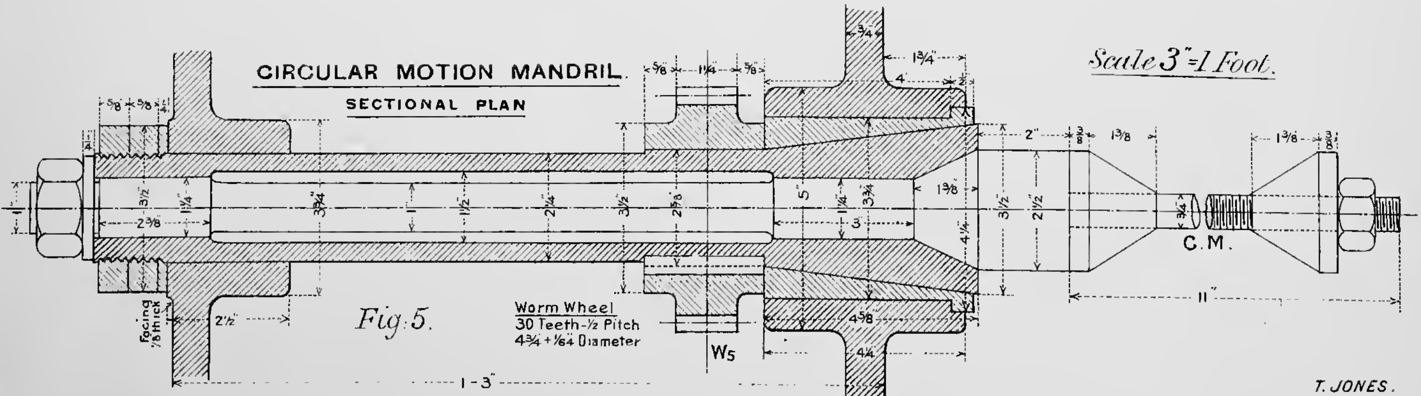

Fig. 5.

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Plate XXI.—SHAPING MACHINE.

DETAILS OF CARRIAGE, &c.—The carriage **Y** is designed to carry the ram **R** and the mechanism actuating it. As in the Slotting Machine, the quick return of the tool is effected by a slotted arm and driving crank, the arm being connected with the ram by the wrought-iron rod **K**.

The sectional elevation (Fig. 2) shows clearly how the driving pinion and wheel **W_1**, **W_2** respectively are supported at the back of the carriage: **W_1** is fitted with a feather key, so that it may receive the motion of the shaft during its travel with the carriage along the bed. On the face of the wheel **W_2** is the **T** slot in which the driving pin **P** is adjusted to give the required stroke of the tool. This pin consists of three parts—a cast-iron block sliding in the slot of the arm **S A**, a wrought-iron flanged bush passing through the block, and a $\frac{7}{8}''$ bolt to hold them in position on the wheel.

The cast-iron slotted arm is centred on the bracket of the carriage, and has attached to it on one side the rod **K** in such a position that when the pin is at its greatest distance from the centre of the wheel the stroke of the ram is 10″. In consequence of the point of attachment of the rod not being on the centre line of the arm, the rate of change of velocity during the first portion of the stroke is greater than that during the latter portion. The maximum velocity occurs a little before half stroke, and assuming the slowest speed of running, *i.e.*, 20·7 revolutions per minute, its value is 38·4ft. per minute for a stroke of 10″. (See below for diagrams of velocity.)

The method of determining the ratio of times of cutting and returning for any stroke will be found in the notes on the Slotting Machine, Plate XIV.

The carriage is moved over the horizontal face of the bed by the left-hand screw **S_1**, and its automatic feed per cutting stroke may be varied from ·009″ to ·055″ by adjusting the link **L_1**. The strip to take up the wear of the sliding surfaces is held by four $\frac{5}{8}''$ screws, and adjusted by three $\frac{1}{2}''$ steel set screws.

The ram is constrained to move at right angles to the length of the bed by the parallel bevelled projection and adjustable strip on the carriage, the strip carrying the vertical support for the tool box feed tackle. The connection of the ram with the rod **K** is such that it may be adjusted to bring the tool to any part of the work.

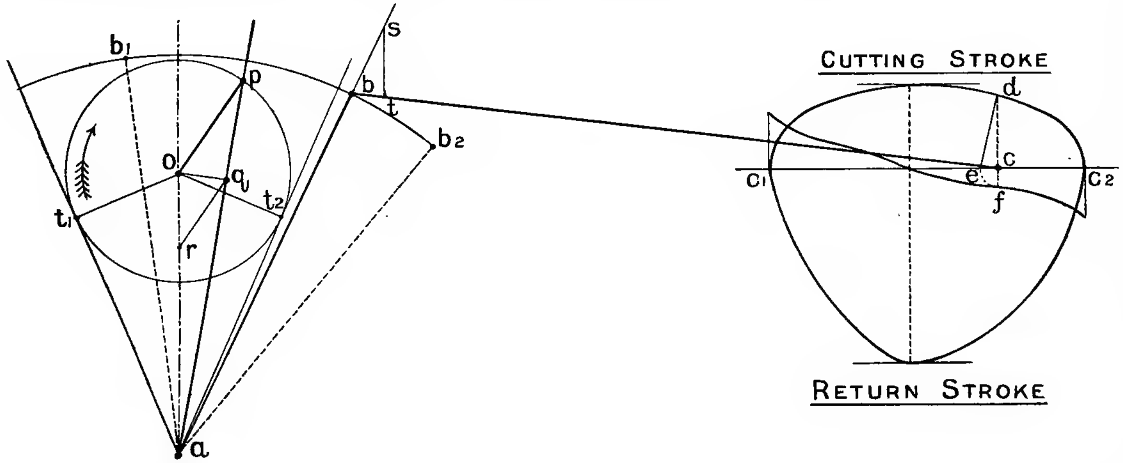
The speed of the driving wheel **W_2** is less than that of the driving shaft in the ratio of 12 to 42; therefore, since the speeds of the latter are 198·6, 120, and 72·5 revolutions per minute (see notes to Plate XXIII.), the number of cutting stroke may be—

$$198{\cdot}6 \times \frac{12}{42} = 56{\cdot}2 \text{ per minute.}$$

$$120 \times \frac{12}{42} = 34{\cdot}3 \quad ,,$$

$$\text{or } 72{\cdot}5 \times \frac{12}{42} = 20{\cdot}7 \quad ,,$$

CURVES OF VELOCITY AND ACCELERATION OF TOOL.—The accompanying diagram gives the velocity and acceleration curves of the tool for the cutting stroke, and the velocity curve for the return, when the stroke is the maximum 10″.



When dealing with a similar problem on the Slotting Machine, it was assumed that the velocity of the tool was equal to the linear velocity of the end of the arm, because the inclination of the connecting rod to the direction of motion to the tool was, for all positions, very small, but with this machine such is not the case, and the effect of this obliquity must be considered.

Let *o* be the centre of the driving wheel; *a* the centre of oscillation of the arm; *p* the driving pin, whose distance from *o* is such as to make the travel of the tool equal to 10″. The extreme positions of the centre line of the arm are $a\,t_1$ and $a\,t_2$ respectively.

The angular velocity for the position *p* of the pin is found by drawing *oq* at right angles to *a p* and *qr* parallel to *op*.

Or represents the angular velocity of the arm, and *oa* the constant angular velocity of the radius *op*. (For proof, see notes to Plate XIV.)

The forked end *b* of the connecting rod *bc* is $3\frac{3}{8}''$ in front of the centre line of the arm, and therefore *ab* must be regarded as a crank of variable angular velocity actuating the ram. The extreme positions b_1, b_2 correspond with the respective positions c_1, c_2 of the tool.

[*Continued.*

10" STROKE SHAPING MACHINE.

DETAILS OF CARRIAGE, DRIVING WHEELS, Etc

Scale 2"=1 Foot.

SIDE ELEVATION

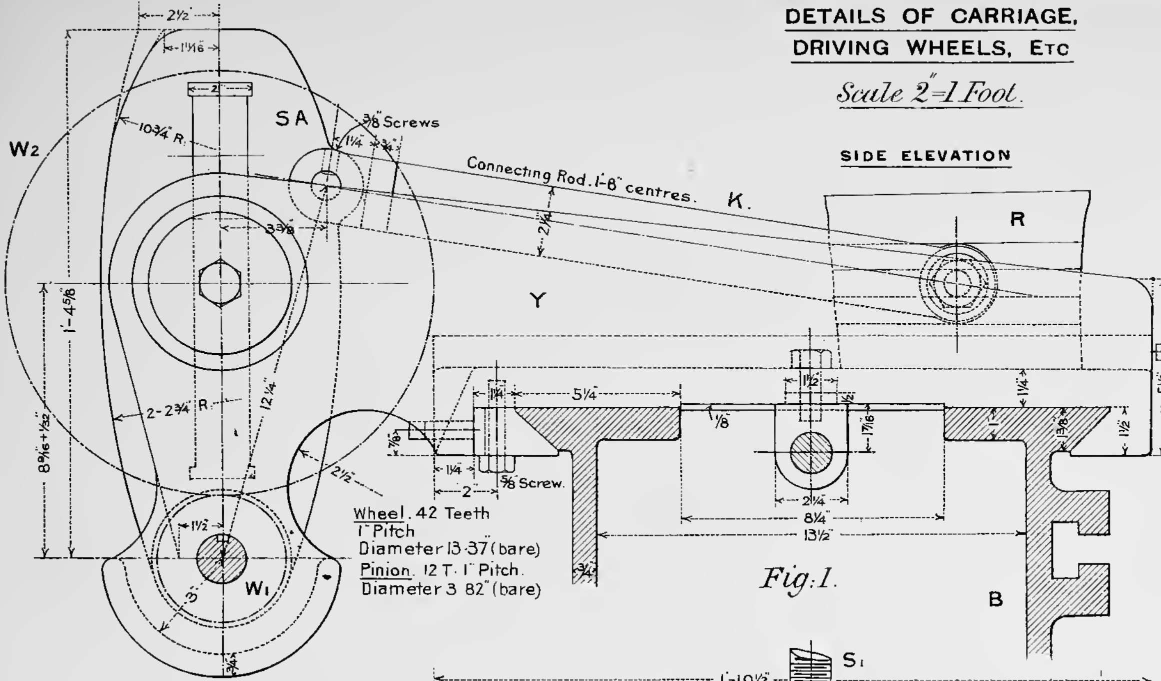
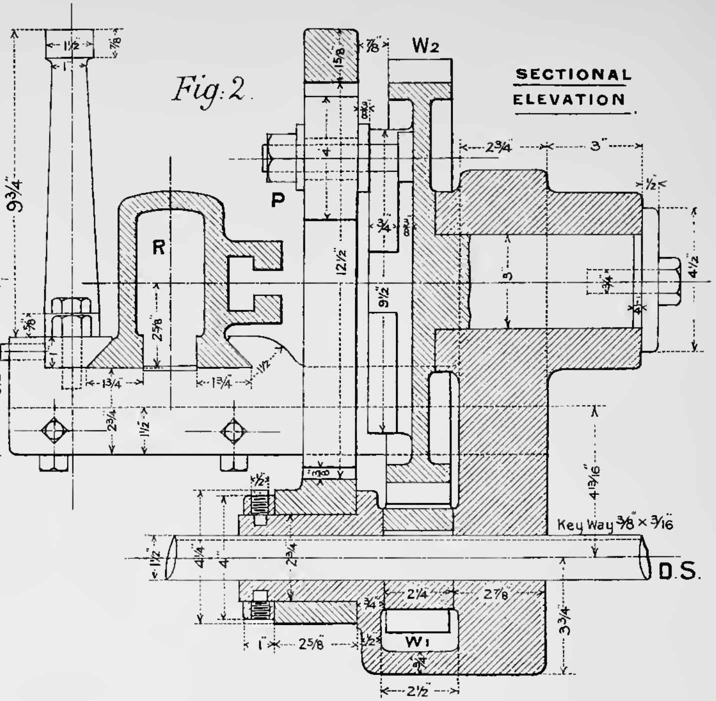


Fig:1.

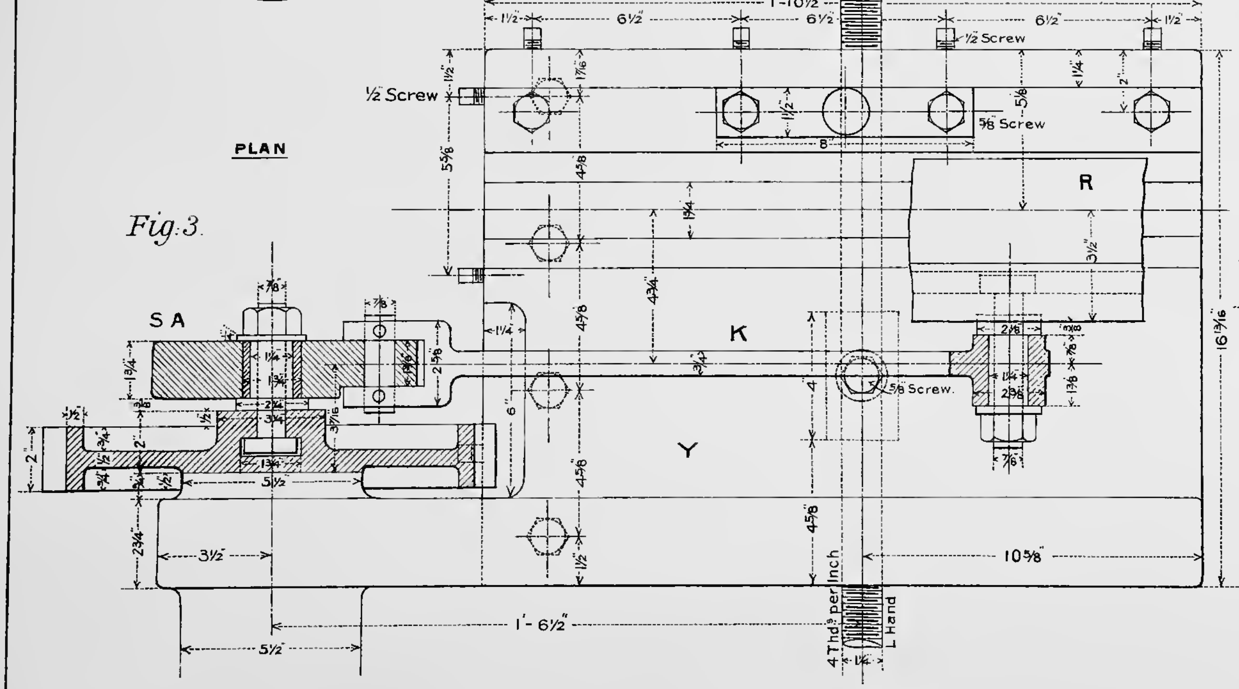
Fig:2.

SECTIONAL ELEVATION.



PLAN

Fig:3.



FLY WHEEL FOR DRIVING SHAFT.

Scale 3"=1 Foot

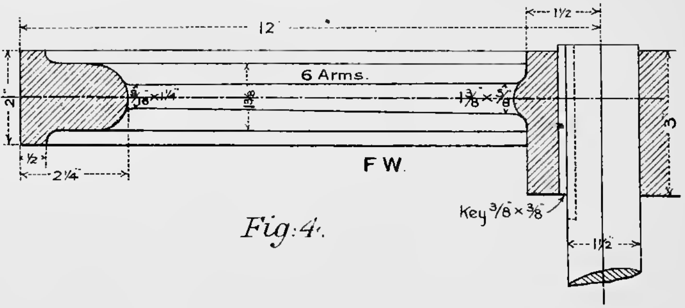


Fig:4.

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Or represents the angular velocity of the arm, but it will now be taken to represent the linear velocity of the point b. The ends b and c of the rod move along the circular arc $b_1\, b\, b_2$ and the straight line $c_1\, c_2$ respectively. For any position the relative velocities of b and c may be determined graphically by the method of *instantaneous centre.*

This centre is such that, at the particular instant considered, the distance from it of any point on the moving body is proportional to the linear velocity of that point.

Through the points c, b draw at right angles to their instantaneous directions of motion, the lines $c\,\mathrm{I}$, $b\,\mathrm{I}$ respectively (not shown in the diagram), intersecting in the point I the instantaneous centre of the rod in the position $b\,c$.

Then, if $b\,\mathrm{I}$ represents the linear velocity of b, $c\,\mathrm{I}$ represents that of c.

On $b\,\mathrm{I}$ make $b\,s$ equal to $o\,r$, and from s draw $s\,t$ parallel to $c\,\mathrm{I}$, intersecting $b\,c$ in t; then $s\,t$ represents the linear velocity of the point c, and therefore of the tool for the position p of the driving pin. Make $c\,d$ on $c\,\mathrm{I}$ equal to $s\,t$. The locus of d is the velocity curve of the tool for the cutting stroke.

The maximum velocity occurs a little before half stroke: for the position $a\,o$ of the arm the linear velocity of c is equal to that of b, and neglecting the very slight difference between this and the maximum velocity, we may say that the **greatest speed of cutting is 38·4ft. per minute.**

Revolutions of driving wheel $= 20{\cdot}7$ per minute, $o\,p = 3\tfrac{1}{2}''$, $a\,o = 8\tfrac{19}{32}''$, $a\,b = 12\tfrac{1}{4}''$; $\therefore$ velocity of $p = \tfrac{2}{1} \times \tfrac{22}{7} \times \tfrac{7}{2} \times \tfrac{1}{12} \times 20{\cdot}7 = 37{\cdot}9$ft. per minute;

$$\text{velocity of } b = \frac{37{\cdot}9 \times 12\tfrac{1}{4}}{12\tfrac{3}{32}} = 38{\cdot}4\text{ft. per minute.}$$

For a complete explanation and proof of the method of drawing an acceleration curve from a velocity curve on a distance base, see Kennedy's "Mechanics of Machinery." The following is the construction:—Draw the normal $d\,e$ to the curve at d, intersecting the base in the point e. The projection $c\,e$ of $d\,e$ on the base represents the acceleration for the position c. $c\,f\,[=c\,e]$ is marked on the ordinate of d above or below the base line $c_1\,c_2$ according as the velocity is increasing or decreasing.

Plate XXII.—SHAPING MACHINE.

DETAILS OF TOOL BOX.—The tool box is constructed so that the tool can be made to cut horizontal, inclined, internal and external cylindrical surfaces. It consists of the slides **N** and **O** and the segmental worm wheel **P** carrying the tool holder.

The back slide **N** is fixed to the circular flange of the ram by three $\tfrac{5}{8}''$ bolts, whose heads fit into a circular **T** groove in the former. To keep the slide central when turned into an inclined position, it moves upon a circular projection on the face of the ram.

Movable over the face of **N** is the slide **O**, carrying on the top and front the worm bracket and wheel segment respectively. The overhanging portion at the top is bevelled inwards at an angle of 50° to receive the curved edge of **P**, which has its centre on the axis of the pin $\mathbf{V}_c$. The brass nut for the feed screw $\mathbf{S}_5$ is fixed to **O** by a $\tfrac{3}{8}''$ set screw as shown in Fig. 2. The dimensions of the adjustable strip for the slide are given in the section at **X Y.**

The worm bracket is recessed to receive the wrought-iron worm **Q**, and its sides are bossed out to support the steel spindle. The malleable iron tool holder **H** on the front of **O** is supported by a pin passing through both, and fitted so that the holder turns slightly upon it when the tool is making the return stroke. The tool is passed into a rectangular recess, $1\tfrac{3}{8}'' \times 1\tfrac{1}{8}''$ (the latter dimension is not given on the drawing), and held securely by two $\tfrac{5}{8}''$ steel screws.

When the slide **N** is vertical the tool can be fed automatically by means of the arrangement shown in Figs. 1, 2, and 4 and the general drawing on Plate XVIII. Fitting on the square end of the screw $\mathbf{S}_5$ is a short cylinder carrying the ratchet wheel and the two sides of the pawl lever, the latter turning freely on it. On one end of the lever is the pawl, and on the other a simple **U** piece for attachment to the feed rod **F R**, which rod is held horizontally by passing through a swivel on the top of the upright fixed on the carriage. This rod carries stops, one on each side of the swivel, so adjusted that near the end of each stroke a stop comes in contact with the fixed swivel, and in consequence the rod is moved a distance equal to that which the ram has still to travel when the stop is arrested. This motion may be varied within wide limits. The pawl must be placed in gear with the teeth of the ratchet wheel on that side of the lever which will cause the feed to be given at the end of the return stroke.

The amount by which the tool may be tilted, while retaining the vertical feed, is limited by the length of the curved slot in the segmental wheel.

If the tool is to cut a concave cylindrical surface, the locking screw is removed and the worm shaft turned through a small angle at the end of each return stroke. The distance of the point of the tool from the centre of the swivel pin $\mathbf{V}_c$ is equal to the radius of the curved surface.

Fig. 3.—The hollow cast-iron ram **R**, movable across the carriage and actuated by the slotted arm and sliding block, carries the tool box on the front end. It is stiffened by two intermediate webs $\tfrac{5}{8}''$ thick, widened to $2\tfrac{1}{2}''$ at the bottom. On one side is the **T** slot, which admits of a horizontal adjustment of about 12″. There is a recess on the top, immediately behind the flange, to receive one of the nuts used in fixing the back slide of the tool box.

10″ STROKE SHAPING MACHINE.

TOOL BOX.

Scale 4″=1 Foot

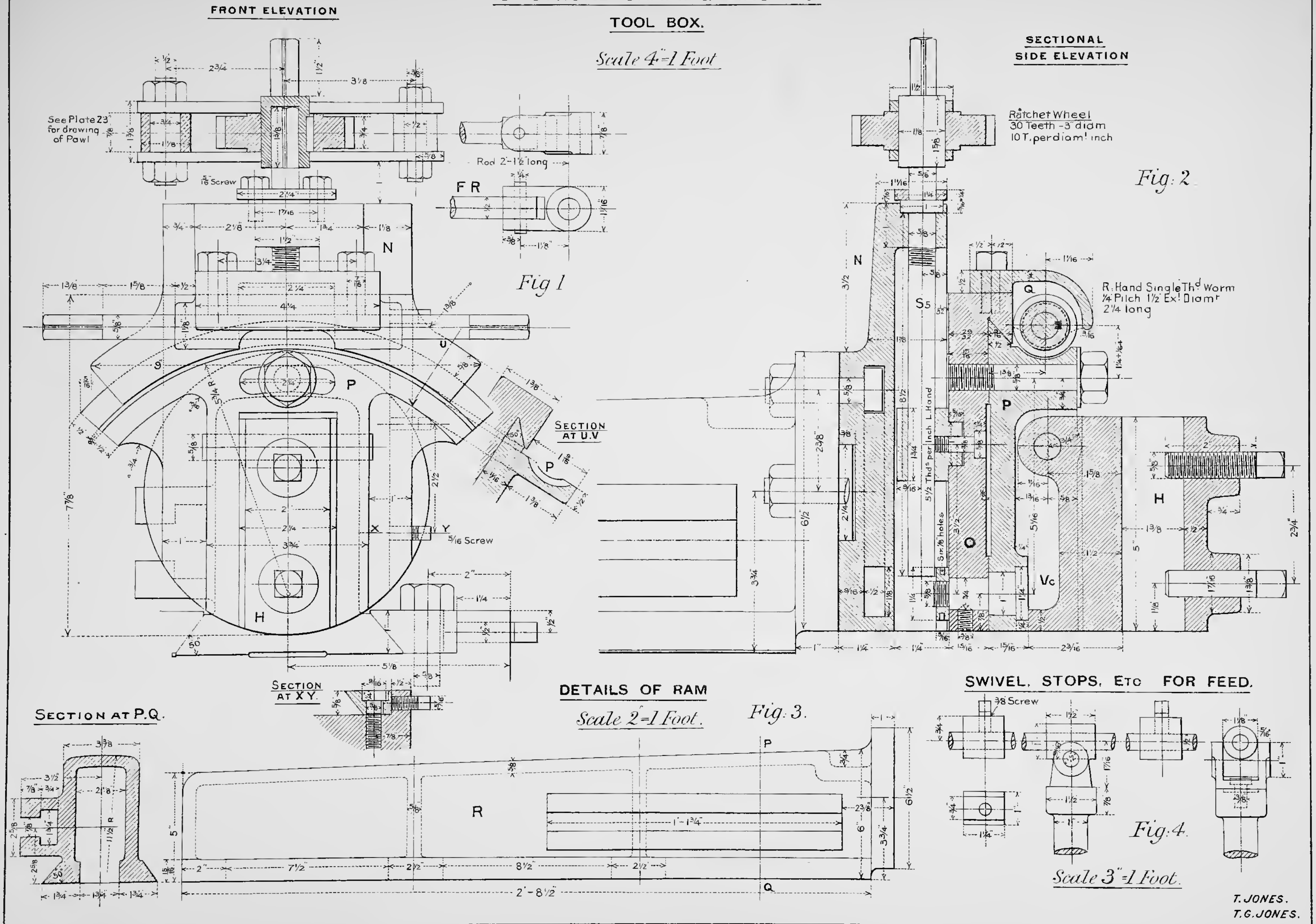

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Plate XXIII.—SHAPING MACHINE.

DETAILS OF FEED MOTION AND DRIVING PULLEY.—The power is transmitted to the machine through the three speed cone pulley on the driving shaft **DS** connected with an equal pulley on the counter-shaft which makes 120 revolutions per minute. To relieve the boss of the pulley from strain due to the pull of the belt four webs are cast between it and the rim.

The three speeds of the shaft are—

Maximum ...... $\frac{120 \times 12\frac{5}{8}}{7\frac{5}{8}} = 198{\cdot}6$ revolutions per minute.

Intermediate ... $= 120$ „ „

Minimum ...... $\frac{120 \times 7\frac{5}{8}}{12\frac{5}{8}} = 72{\cdot}5$ „ „

On the other end of the shaft, outside the arm **E**, is fixed the 2ft. fly wheel, shown on Plate XXI., Fig. 4, which ensures more uniform running during the variable speed of cutting.

The feed gear is designed to effect automatically the feeds of the carriage and the circular motion mandril. Carried on the arm **E** are the feed wheel W_4 and the lever **F**; and on the end of the screw S_1 are two wheels G_1 G_2, the former keyed to S_1, and the latter turning freely on the long boss of G_1 and in gear with an equal wheel G_3 on the worm shaft S_2.

The feed pinion W_3, gearing with W_4, is fixed on the driving shaft. The ratio of the numbers of teeth on W_3, W_4 is the same as that of the driving pinion and wheel W_1, W_2 respectively; *i.e.*, $\frac{26}{91} = \frac{12}{42}$, so that the wheel provided with the circular groove for feed makes one revolution per double oscillation of the slotted arm **SA**.

The eccentricity of the groove is $1\frac{1}{4}''$, and therefore the steel bowl on the end of the cast-iron feed lever performs two vertical strokes, each $2\frac{1}{2}''$ long, per revolution. The vibrating motion is transmitted to the cast-iron bell-crank pawl lever L_2 by the link L_1 whose ends are adjusted in the slots to give the required feed. The maximum and minimum angular displacements of L_2 are about 80° and 13° respectively. (See diagram below.)

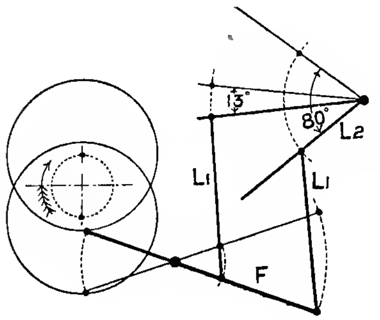
Since the feed groove is circular the pawl lever will be continually moving, the pawl either moving the ratchet wheel forward or slipping over its teeth, and therefore the feed must commence before the end of the return stroke and continue during a portion of the cutting stroke. The best position of W_4 relative to the driving wheel W_2 is determined on the machine itself. Undoubtedly the feed motion would be better if a groove of shape similar to that for the slotting machine were used.

When the feed of the carriage along the bed is required the pawl above the wheel G_1 is turned into gear.

The wheel G_3 is keyed to the worm shaft S_2, so that when wheel G_2 is moved by the pawl the circular motion mandril will receive a slight angular displacement, varying in amount from $\frac{13}{30}°$ to $2\frac{2}{3}°$ depending upon the position of the link L_1. L_2 turns freely on S_1, and is held in position by a collar pinned to the latter.

Handles are used on the ends of the screw and shaft for rapid adjustment by hand.

CALCULATION OF FEED.—The maximum and minimum angles turned through by the pawl lever are 80° and 13° respectively.



(*a*) *Feed of Carriage.* Pitch of screw = $\frac{1}{4}''$.

Maximum = $\frac{80}{360} \times \frac{1}{4} = \frac{1}{18}''$ [$= {\cdot}055''$] or 18·4 strokes per inch of feed.

Minimum = $\frac{13}{360} \times \frac{1}{4} = \frac{13}{1440}''$ [$= {\cdot}009''$] or 110 strokes per inch of feed.

(*b*) *Angular Feed of Circular Motion Mandril.*—For one revolution of the shaft the wheel moves through $\frac{1}{30}$th of a revolution, or 12°.

Maximum = $\frac{80}{360} \times \frac{1}{30} \times \frac{360}{1} = 2\frac{2}{3}°$.

Minimum = $2\frac{2}{3} \times \frac{13}{80} = \frac{13}{30}°$.

BOOK 2. PLATE XXIII.

10" STROKE SHAPING MACHINE.

DETAILS OF FEED MOTION AND DRIVING PULLEY.

Scale 2"=1 Foot.

ELEVATION OF PAWL LEVER AND RATCHET WHEELS.

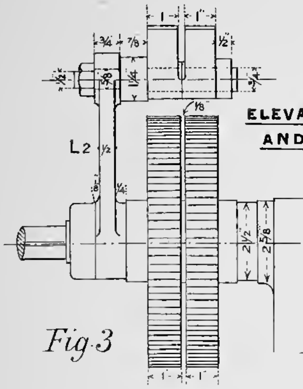
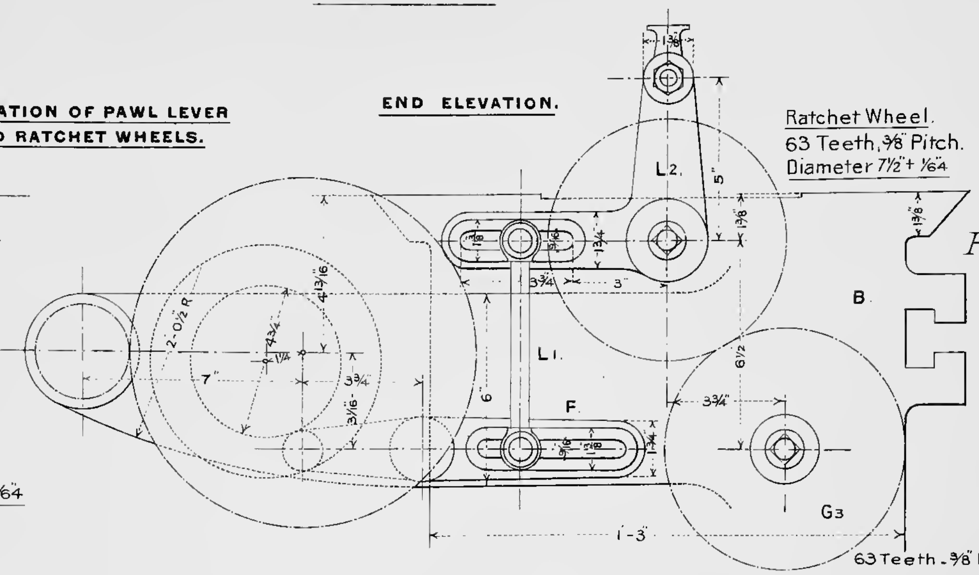


Fig. 3

Wheel. 91 Teeth, 3/8" Pitch.
Diameter 10 7/8".
Pinion. 26 Teeth, 3/8" Pitch
Diameter 3 7/8" less 1/64

END ELEVATION.



Ratchet Wheel.
63 Teeth, 3/8" Pitch.
Diameter 7 1/2" + 1/64

Fig. 1.

63 Teeth, 3/8" Pitch.

SECTIONAL PLAN.

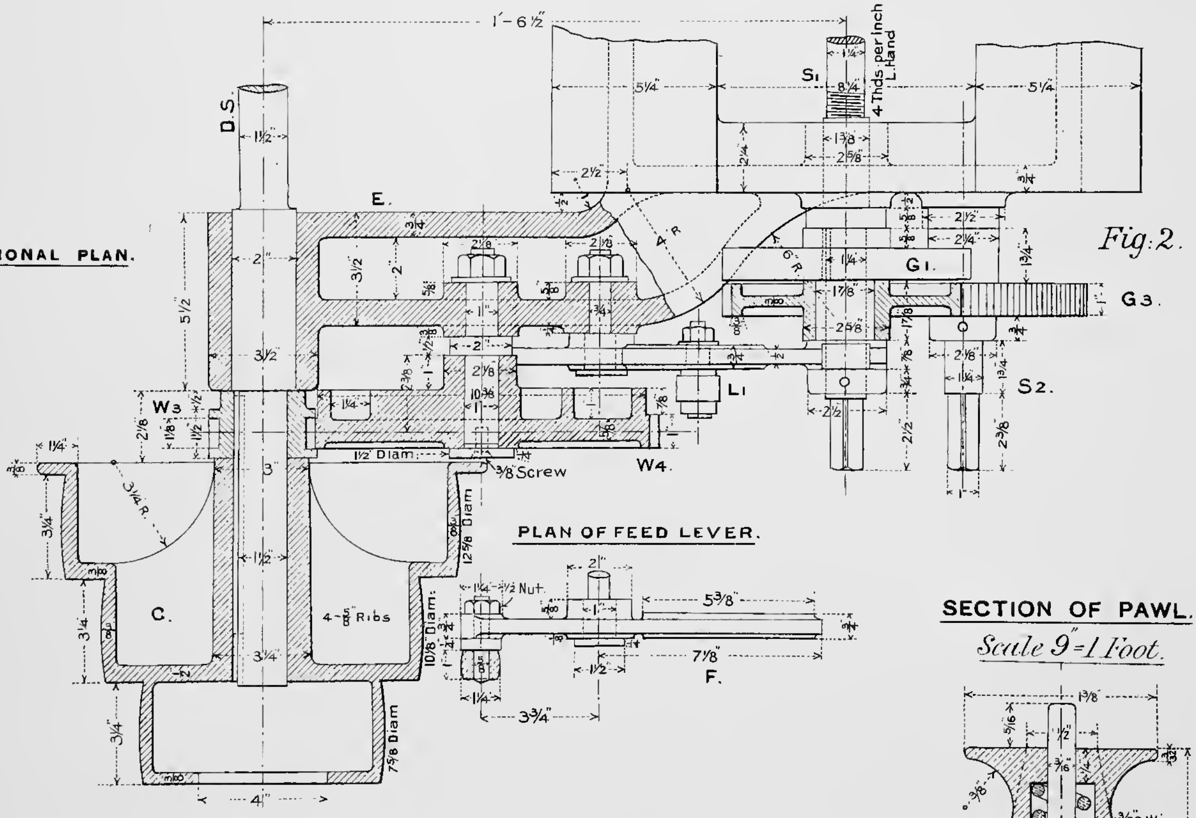


Fig. 2.

CONNECTING LINK.

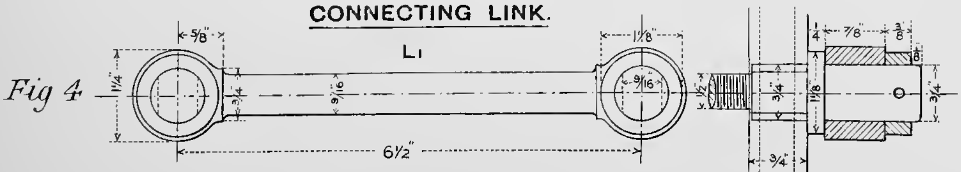


Fig. 4

Scale 3/8 full size.

SECTION OF PAWL.

Scale 9"=1 Foot.

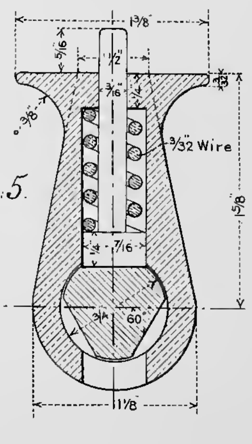


Fig. 5.

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Plate XXIV.—WORM AND WORM WHEEL.

A WORM and a worm wheel are used to connect two non-intersecting shafts at right angles when the angular velocity ratio is large. The worm is simply a short length of screw, with a special form of thread, supported in bearings so that motion parallel to its axis is not possible. The teeth on the worm wheel, if correctly shaped, are such as to have contact with the worm thread along the entire width. Often, however, the teeth are made of uniform section across the rim—being merely twisted spur wheel teeth—and then there is only contact between the thread and a tooth at a point in the central plane. This defect gives rise to excessive friction and wear in the gearing.

The sections of the thread and teeth by the central plane on the worm and wheel respectively are the same as for a rack and wheel, the latter having the same diameter as the worm wheel. For convenience in turning the worm, the involute form of tooth is usually adopted, and then the thread is of triangular section, having an angle of 31°—*i.e.*, double the angle of obliquity, $15\frac{1}{2}°$—at the point. The proportions of a tooth are as follows:—

Thickness of tooth on pitch line, 0·48 pitch. | Height above pitch line, 0·3 pitch. | Depth below pitch line, 0·4 pitch.

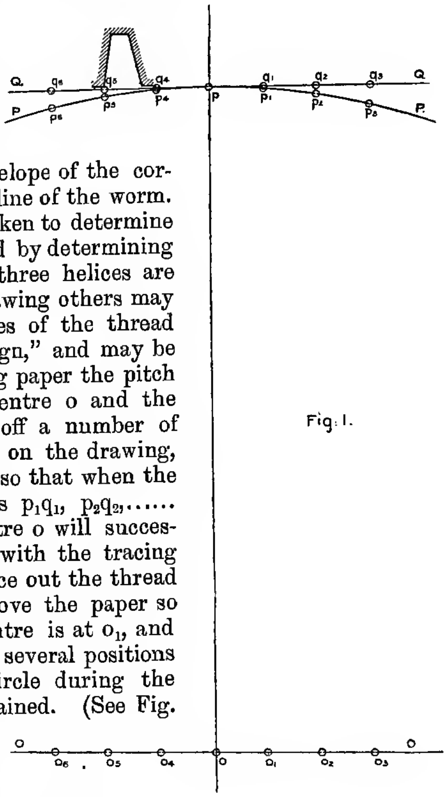


Fig. 1.

When drawing the worm the radial or central section is first obtained, and then helices of 1″ pitch are drawn on the cylindrical surfaces through the four points of the section. (See Plate VI., Book I., for method of drawing the projection of a screw thread.) The central section of the wheel tooth is formed of involutes of the base circle tangential to the path of contact that makes an angle of $15\frac{1}{2}°$ with the pitch line of the worm. To secure line contact between the thread and a tooth, any section of the latter must be the envelope of the corresponding thread section, when the pitch circle of the wheel rolls on the pitch line of the worm. In the drawing three sections *bb*, *cc*, *dd*, other than the central one, have been taken to determine the form of a half tooth. Points on the section of the worm thread are obtained by determining the intersections of the helices on the thread with the section plane. Only three helices are shown, viz., those through the point, root and pitch point, but on a larger drawing others may conveniently be introduced. The best method of determining the envelopes of the thread sections is described by Professor Unwin, in his "Elements of Machine Design," and may be given as follows: Draw on a sheet of tracing paper the pitch circle PP of the wheel, showing clearly the centre O and the initial pitch point *p*. Beginning at *p*, mark off a number of equal lengths along PP on the tracing and PP on the drawing, and also on OO, the locus of the centre of O, so that when the pitch circle rolls upon the line QQ, the points p_1q_1, p_2q_2,...... p_6q_6 will in turn be coincident, whilst the centre O will successively have the positions $o_1, o_2 ...... o_6$. Start with the tracing paper in the position shown in Fig 1, and trace out the thread section whose envelope is required. Now move the paper so that the points p_1q_1 are coincident, and the centre is at o_1, and again trace the section. By proceeding so, the several positions of the section, with respect to the pitch circle during the driving of the wheel by the worm, will be obtained. (See Fig. 2.) The tooth section to work with the thread in the plane of section is the envelope of these positions when allowance has been made for a side clearance of $[0·52p - 0·48p =]0·04p$, and a top clearance as determined from the sectional elevation.

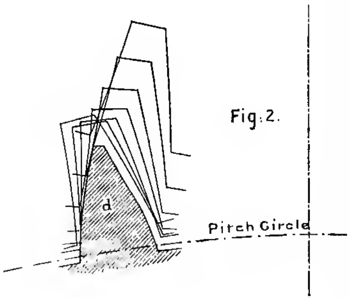


Fig. 2.

The sections b,c,d, when reversed are the corresponding ones for the other half tooth.

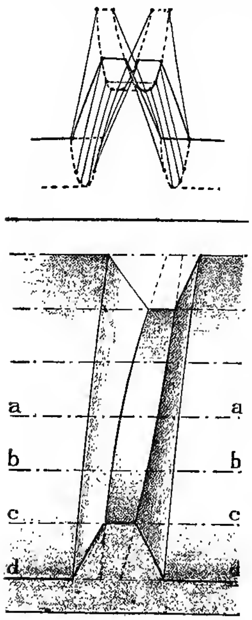


Fig. 3.

If the drawing of the worm is large enough to permit making all the sections on the same portion of thread, the tooth sections, when transferred to the drawing paper will be those of a single tooth in their exact relative positions. Whether this plan has been adopted or not, all the tooth sections must now be drawn on tracing paper (see Fig. 3) as sections of one tooth, and placed over the drawing, so that the central section coincides with the same section underneath. Then, projecting from the four points of each section the plans of the lines of a tooth are obtained. It will be seen that the point thickness at the ends is less than in the centre. The section dd is taken to determine the root thickness at the side of the wheel rim, and also the better to obtain the projections of the top edges.

If the worm is single threaded, and the wheel has *n* teeth, the velocity ratio is 1 : *n* and the theoretical mechanical advantage *n*. For double and treble threaded worms the velocity ratios are $1 : \frac{n}{2}$ and $1 : \frac{n}{3}$ respectively.

The **efficiency** of worm gearing is greater the less the radius of the worm. It varies from 0·25, for a single threaded worm when its radius is three times the pitch, to 0·66, when the worm has three threads and $r = 1·5$ p. That this form of gearing is not very inefficient when the wheel teeth are correctly cut is evident from the following note taken from "Engineering," of November 19th, 1897.

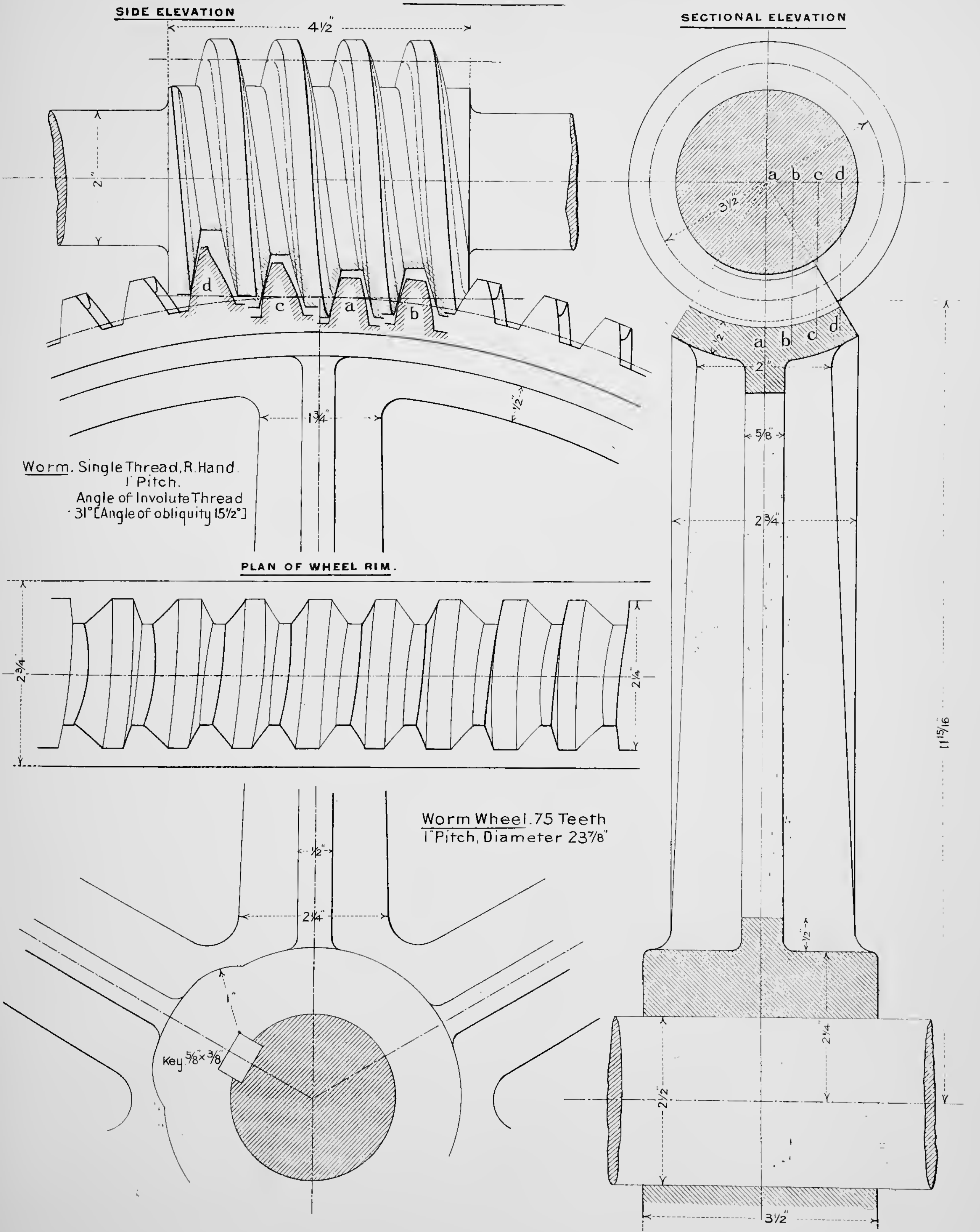
"Professor Strodola, of Zurich, has obtained an efficiency of 87 per cent, when using worm gearing to transmit 21 H.P., the worm running at 1,500 revolutions per minute. This worm was 3·15in. in diameter, the pitch being 3·2in., and the wheel, which was of gun-metal, had 28 teeth."

A description of a machine for accurately cutting worm-wheel teeth is given by Mr. Gibson in a paper recently read before the North-East Coast Institution of Engineers and Shipbuilders. This appeared in "Engineering," for April 2nd, 1897.

WORM AND WORM WHEEL.

PLATE XXIV

Scale ½ full size



Worm. Single Thread, R. Hand.
1" Pitch.
Angle of Involute Thread
31° [Angle of obliquity 15½°]

Worm Wheel. 75 Teeth
1" Pitch, Diameter 23⅞"

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Plate XXV.—DOUBLE HELICAL SPUR WHEELS.

WHEN two ordinary spur wheels are in gear the point of application of the pressure exerted between a pair of teeth is continually changing. If the profiles of the teeth are formed of cycloidal curves, the path of the point of contact is made up of the portions of the describing circles intercepted between the point circles of the two wheels. (See Fig. 1.)

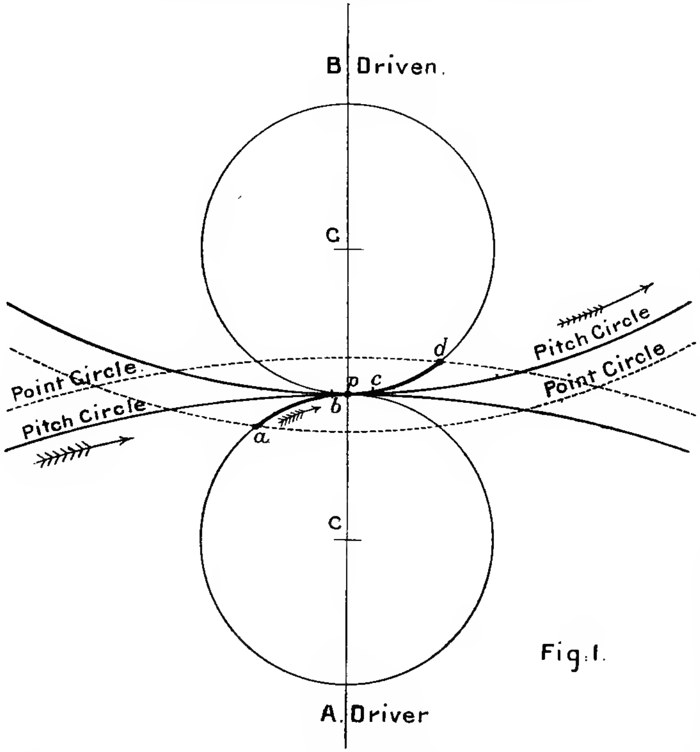


Fig. 1.

If **A** is the driving wheel, contact begins at *a* and ends at *d*.

Neglecting the deviation of the direction of pressure from the normal to the profiles of the teeth at the point of contact on account of the frictional resistance to sliding, the direction of pressure always passes through the pitch point *p*. Consequently, it is only when the teeth are passing the centre line that the pressure exerted between them is wholly effective in producing rotation.

The obliquity of action is greatest at the beginning and ending of contact. (The obliquity is usually limited to 30°.)

The continual variation of the direction of pressure is the cause of irregular working of wheels and variable pressure on the bearings, but these objections are entirely removed by the use of accurately machine-moulded helical wheels.

Consider now the action on one another of the teeth of the wheels drawn on Plate XXV., assuming them first to have ordinary straight teeth of $2\frac{1}{4}$ inches pitch.

Using describing circles of $5\frac{1}{4}$ inches diameter, the length of the path of contact *apd* is about $3\frac{5}{8}''$; so that there will always be two pairs of teeth in gear, whose respective points of contact will be *a* and *c*, where *a* and *c* are two points on the curve *apd* and $2\frac{1}{4}''$ (equal to the pitch) apart.

The force transmitted from one wheel to the other is the resultant of the two forces acting at *a* and *c*, having the directions *ap* and *pc* respectively.

If, however, the wheels were divided into a number of narrow ones, and each placed behind the preceding one by a constant amount, the points of contact of the several portions of a pair of teeth would be distributed uniformly along the path of contact: the forces exerted at these points resulting in one more nearly coincident with the tangent through the pitch point *p*. Also, with such stepped wheels the variation in the direction of the resultant pressure is less than with the ordinary straight teeth. When the slices become indefinitely numerous and narrow the tooth becomes a helical tooth, whose centre line is a helical curve traced on the pitch surface of the wheel.

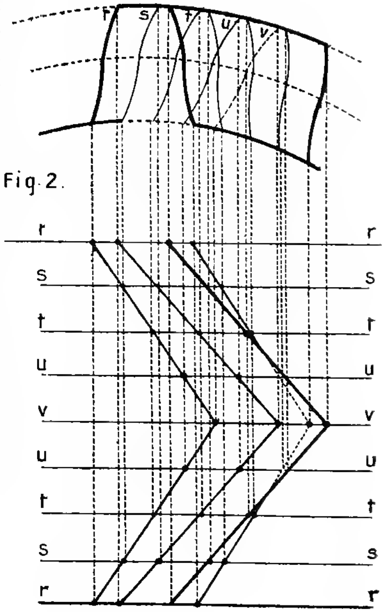


Fig. 2.

To obviate the objection of end pressure on the shafts resulting from the use of single helical wheels, two, having teeth of the same inclination but of opposite directions, are combined to form the double helical wheel.

In the example given the central section of a tooth is $1\frac{1}{2}''$ (*i.e.*, one quarter the width of the wheel) in advance of the ends. Contact between the two pairs of teeth in gear is at the same instant distributed along the arcs *ab* and *cd*, which are each equal to $1\frac{1}{2}''$ in length. If the *lead* of the tooth is equal to, or greater than the pitch, the pressure is exerted along the whole length of the arc *apb*, and the obliquity of action is consequently constant and very small.

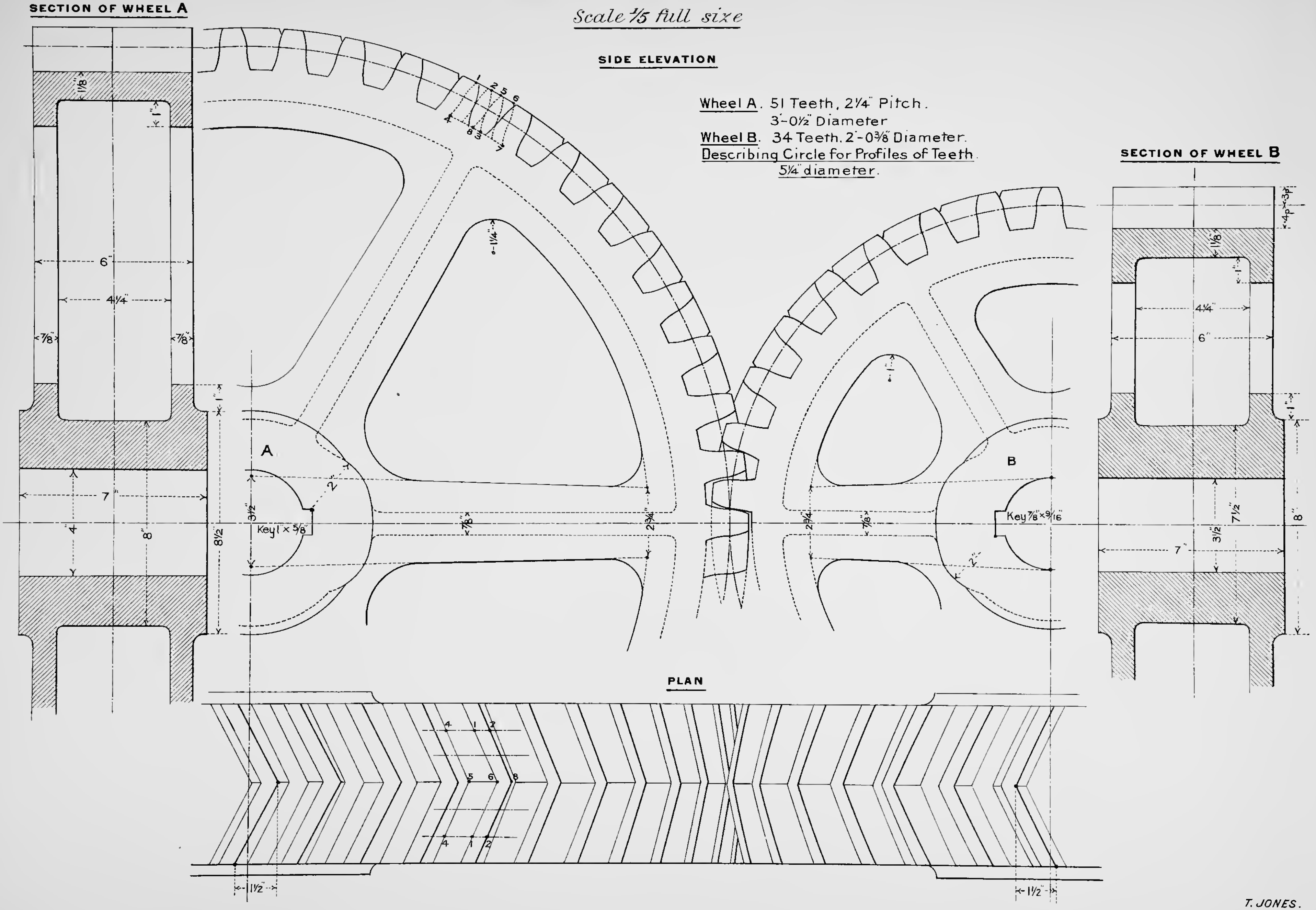
To obtain the projections of a double helical tooth (see Fig. 2) divide the wheel into *n* equal parts by section planes at right angles to the axis of the wheel, and for each section plane draw the section of the tooth; *i.e.*, draw between the ends of half a complete tooth $\left(\frac{n}{2}-1\right)$ equidistant sections. Projecting from the four points of each section into the corresponding section plane, points are obtained on the helical curves of the tooth.

NOTE.—The proportions of a tooth are as follows:—

Thickness of tooth on pitch line ....0·48 pitch.
Height outside pitch line ....0·3 „
Depth below pitch line ....0·4 „

DOUBLE HELICAL SPUR WHEELS.

Scale 1/5 full size



Wheel A. 51 Teeth, 2¼" Pitch.
3'-0½" Diameter
Wheel B. 34 Teeth. 2'-0⅜" Diameter.
Describing Circle for Profiles of Teeth.
5¼" diameter.

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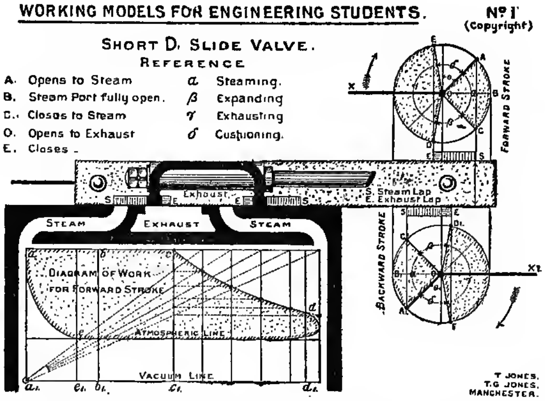

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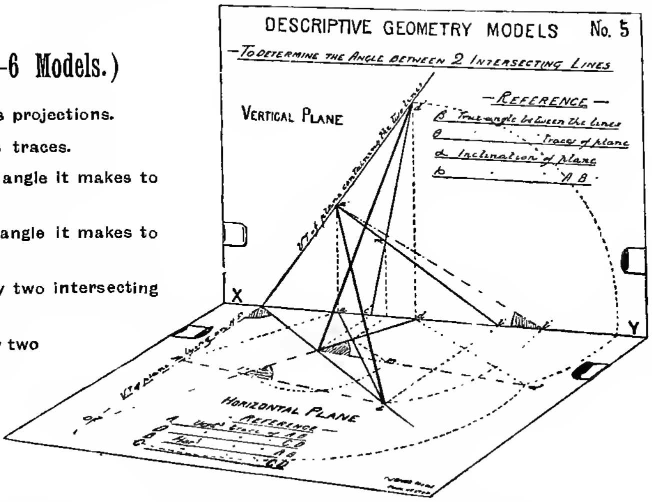
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